US009460172B2

(12) **United States Patent**
Gong et al.

(10) **Patent No.: US 9,460,172 B2**
(45) **Date of Patent: Oct. 4, 2016**

(54) **METHOD TO REDUCE LARGE OLAP CUBE SIZE USING CELL SELECTION RULES**

(71) Applicant: **SAS Institute Inc.**, Cary, NC (US)

(72) Inventors: **Qing Gong**, Cary, NC (US); **Amy Spelman Davis**, Raleigh, NC (US); **Ryan Norris**, Cary, NC (US); **Enrico Stevanoni**, Cary, NC (US)

(73) Assignee: **SAS INSTITUTE INC.**, Cary, NC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 219 days.

(21) Appl. No.: **14/209,739**

(22) Filed: **Mar. 13, 2014**

(65) **Prior Publication Data**

US 2014/0279833 A1 Sep. 18, 2014

Related U.S. Application Data

(60) Provisional application No. 61/779,387, filed on Mar. 13, 2013.

(51) **Int. Cl.**
G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ... ***G06F 17/30563*** (2013.01); ***G06F 17/30592*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 17/30554; G06F 17/30592; G06F 17/3046
USPC 707/600, 756, 602
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,442,560 B1 * 8/2002 Berger G06F 17/18
6,477,536 B1 * 11/2002 Pasumansky G06F 17/30418
6,775,662 B1 8/2004 Witkowski et al.
7,133,876 B2 11/2006 Roussopoulos et al.
7,305,408 B2 12/2007 Morris
7,464,080 B2 12/2008 Cotner et al.
7,584,202 B2 9/2009 Subramaniam et al.
7,805,433 B2 * 9/2010 Dickerman G06F 17/246 707/706
7,970,790 B2 6/2011 Yang et al.
8,521,755 B2 * 8/2013 Mahajan G06F 17/30592 707/756
8,676,801 B2 * 3/2014 Gong G06F 17/30333 707/736
9,223,832 B2 * 12/2015 Hamborg G06F 17/30592
2004/0093412 A1 * 5/2004 Chen G06Q 10/10 709/224
2004/0122844 A1 * 6/2004 Malloy G06F 17/30592

(Continued)

OTHER PUBLICATIONS

Xie et al.,"The Algorithm of Reducing Data Cube Size Rapdly", ISBN 978-1-4244-4639-1, IEEE, Sep. 20-22, 2009, 4 pages.

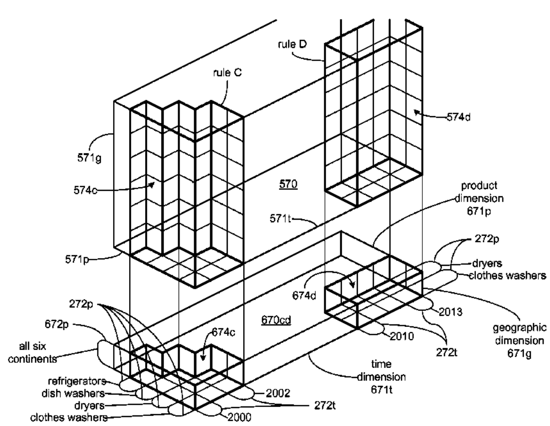
(Continued)

Primary Examiner — Jean M Corrielus

(57) **ABSTRACT**

Various embodiments are directed to techniques for providing one or more reduced-size rule cubes indicating cell rules. A computer-program product embodied in a machine-readable storage medium includes instructions to cause a computing device to select a cell rule to include in a rule cube based on applicability of the cell rule to a selected portion of a data cube; analyze the cell rule to identify a wildcarded dimension in a specification of cells of the data cube that are subject to the cell rule; and generate the rule cube indicating applicability of the cell rule to the selected portion of the data cube, wherein a cell of the rule cube corresponds to multiple cells of the data cube, and wherein the wildcarded dimension of the rule cube is reduced in length in comparison to a length of the wildcarded dimension of the data cube. Other embodiments are described and claimed.

23 Claims, 12 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0085444	A1 *	4/2006	Sarawgi	G06F 17/3046
2007/0088691	A1 *	4/2007	Dickerman	G06F 17/246
2010/0312748	A1 *	12/2010	Dickerman	G06F 17/30592 707/602
2011/0055146	A1 *	3/2011	Mahajan	G06F 17/30554 707/600
2012/0084250	A1 *	4/2012	Gundorov	G06F 17/30592 707/600
2013/0054608	A1 *	2/2013	Gong	G06F 17/30592 707/741
2014/0181002	A1 *	6/2014	Christian	G06F 17/30592 707/600

OTHER PUBLICATIONS

Harinarayan et al., "Implementing Data Cubes Efficiently", SIGMOD '96, Montreal, Canada, 1996 ACM 0-89791-794, 12 pages.

Wang et al., "Condensed Cube: An Effective Approach to Reducing Data Cube Size", Hong Kong University of Science and Technology, 2002, 11 pages.

Sismanis et al., "The Dwarf Data Cube Eliminates the High Dimensionality Curse", University of Maryland—Institute for Advanced Computer Studies, 2003, 11 pages.

"Writeback performance issue when cell security is enabled in SQL Server Analysis Services", Microsoft Support, <http://support.microsoft.com/kb/2747616>, 1 page, (date & author unknown).

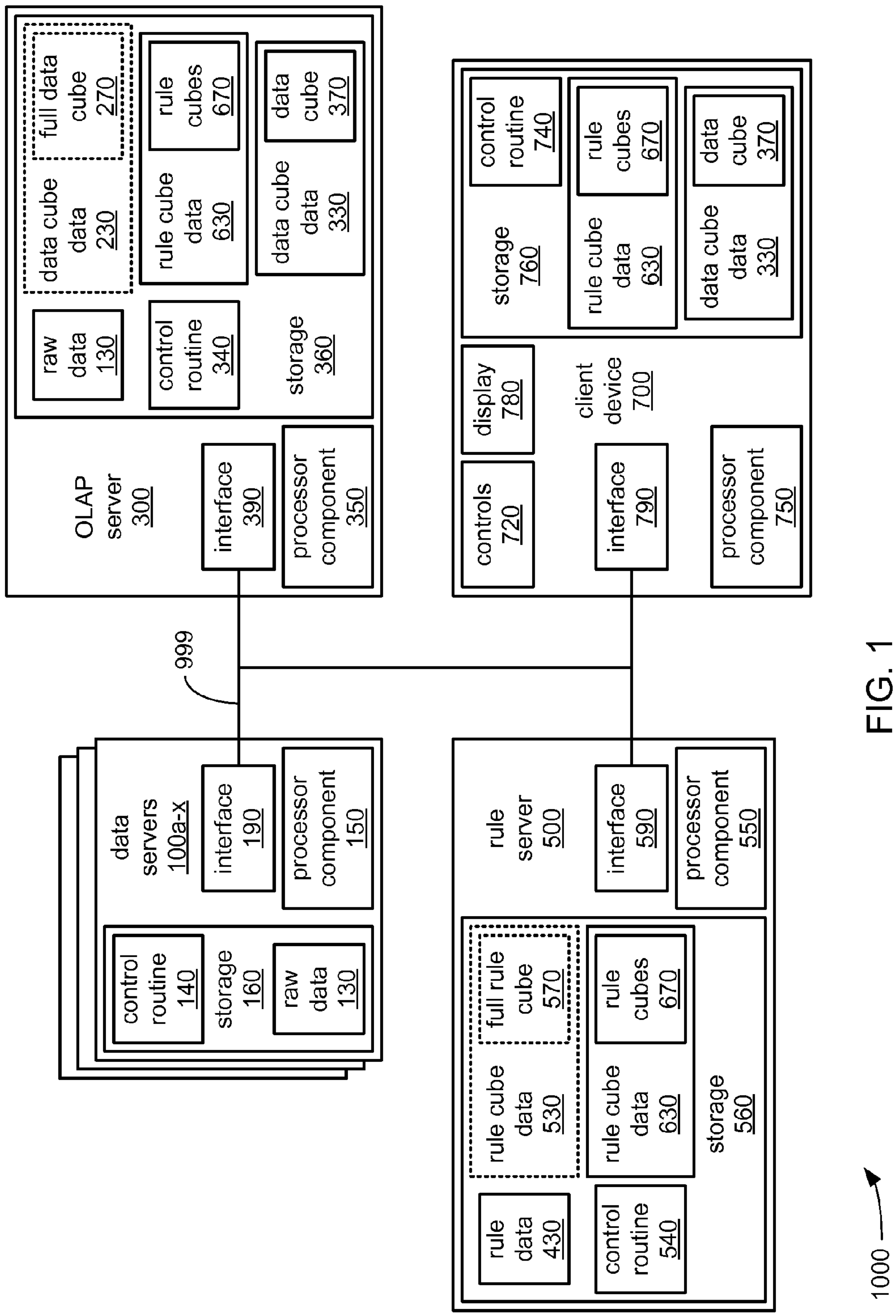
"SP2 + cell data security = performance problem", Microsoft SQL Server, <http://social.msdn.microsoft.com/Forums/en-US/sqlanalysisservices/thread/12f07889-5ea9-4c18-b5d7-69a3bc4d8b17>, 2 pages, Mar. 5, 2007 , (author unknown).

"Performance Improvements for MDX in SQL Server 2008 Analysis Services", Microsoft Developer Network, 2010, 7 pages, (author unknown).

Agarwal et al., "On the Computation of Multidimensional Aggregates", Proc. of the 22 VLDB Conference, Mumbai, India, 1966, 16 pages.

Whitney, Russ, "Mastering OLAP: Cell-level Security", SQL Serverpro, <http://sqlmag.com/querying/mastering-olap-cell-level-security>, Oct. 23, 1999, 5 pages.

* cited by examiner

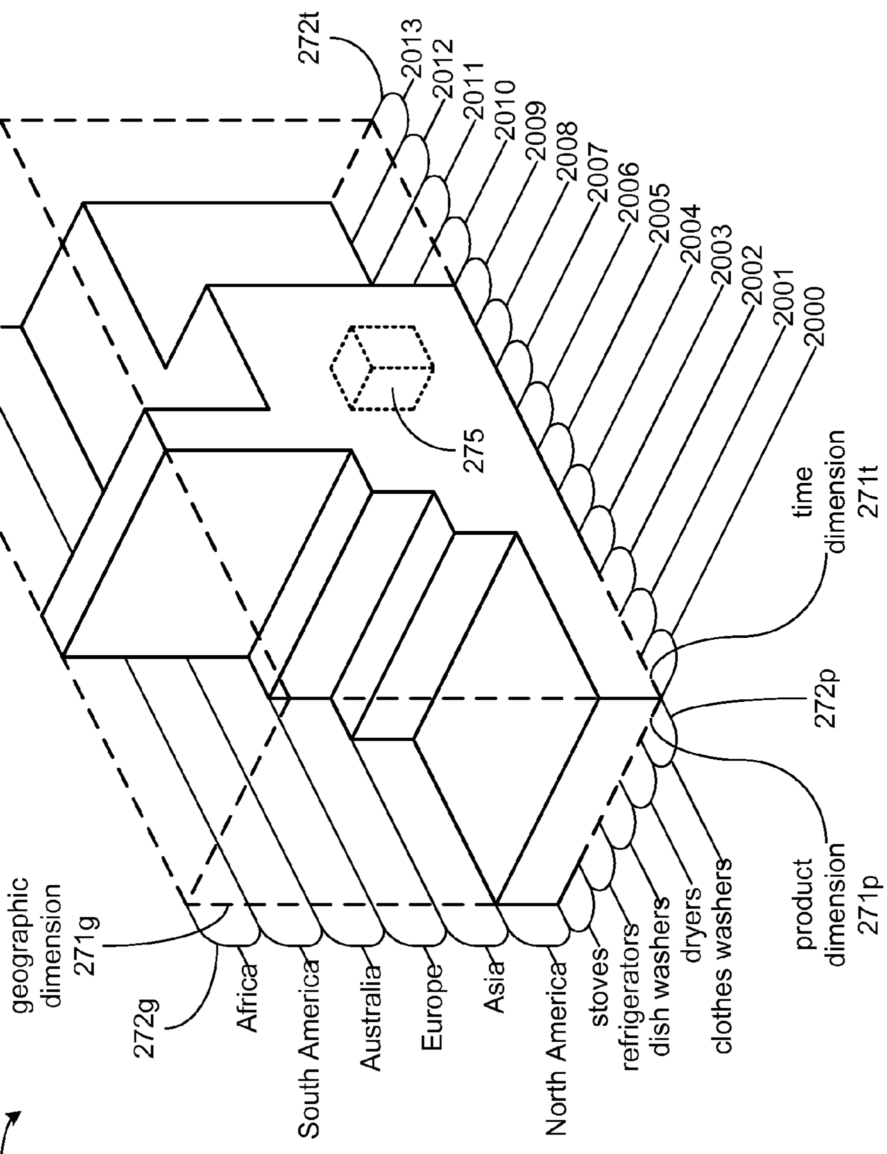


data servers 100a-x
control routine 140
storage 160
raw data 130
interface 190
processor component 150
999
OLAP server 300
raw data 130
control routine 340
storage 360
data cube data 230
full data cube 270
rule cube data 630
rule cubes 670
data cube data 330
data cube 370
interface 390
processor component 350
rule server 500
rule data 430
control routine 540
rule cube data 530
full rule cube 570
rule cube data 630
rule cubes 670
storage 560
interface 590
processor component 550
client device 700
controls 720
display 780
interface 790
processor component 750
storage 760
control routine 740
rule cube data 630
rule cubes 670
data cube data 330
data cube 370
1000

FIG. 1

FIG. 2

270



geographic dimension 271g
272g
Africa
South America
Australia
Europe
Asia
North America
stoves
refrigerators
dish washers
dryers
clothes washers
product dimension 271p
272p
time dimension 271t
275
272t
2013
2012
2011
2010
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000

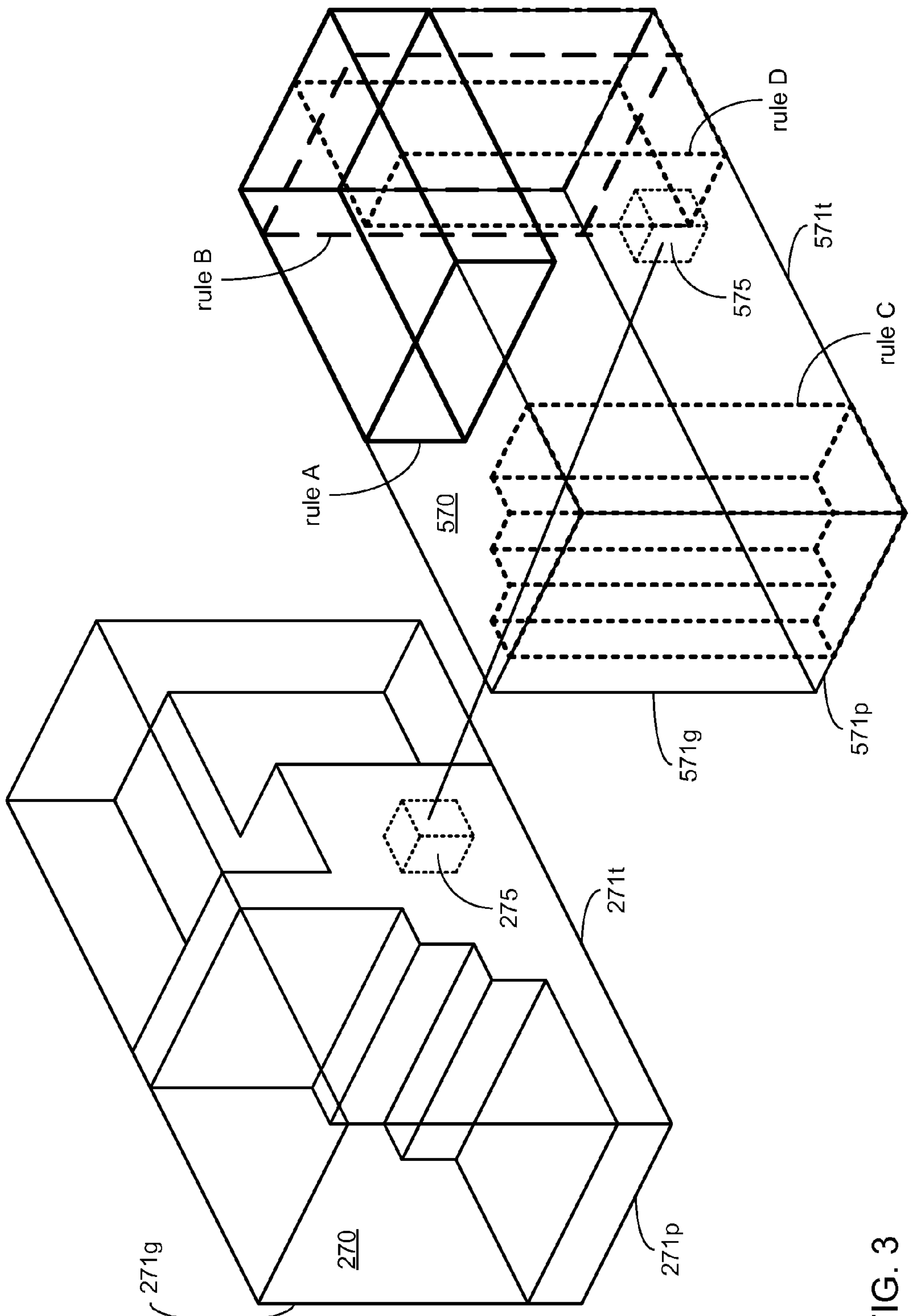
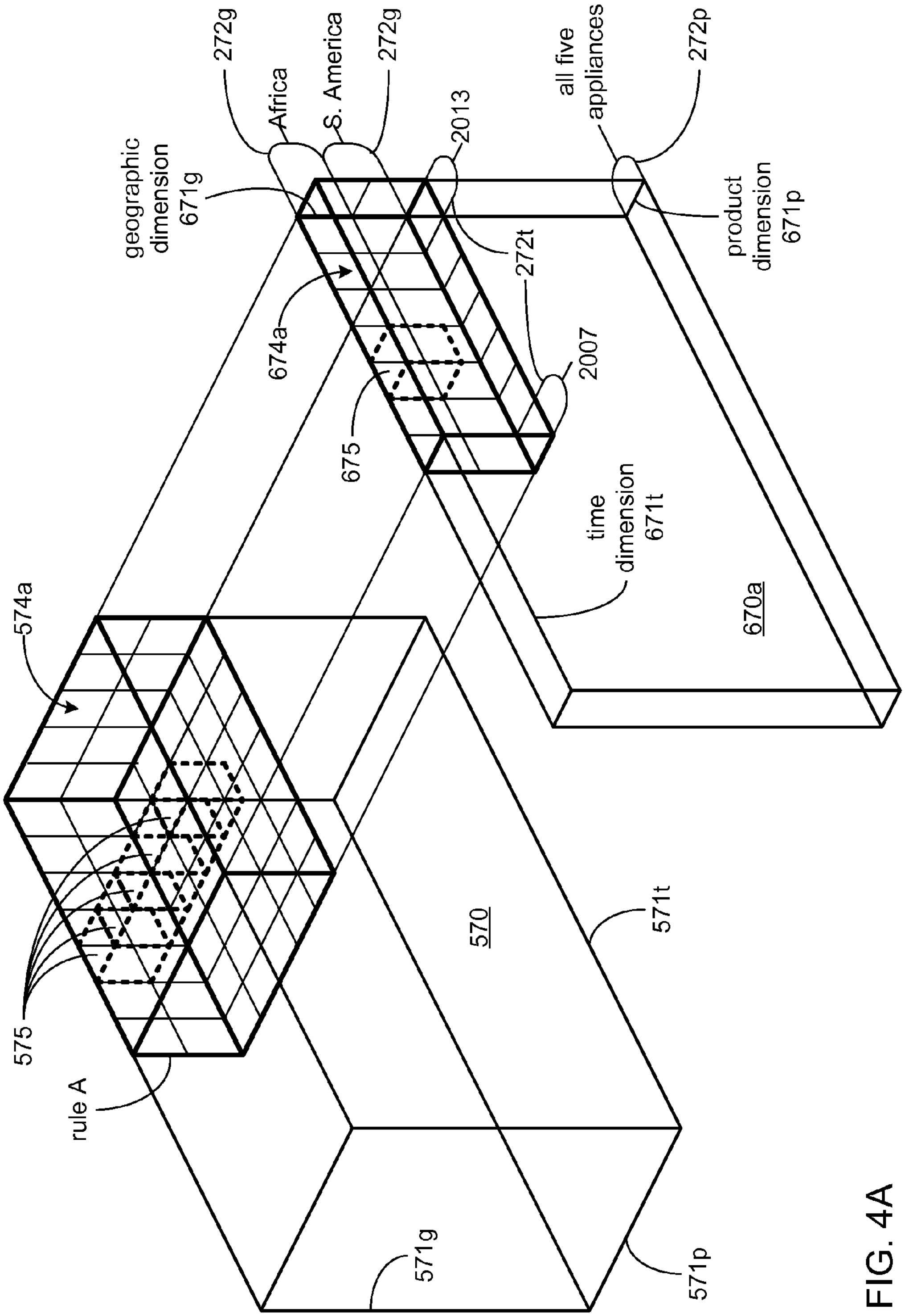

rule B
rule D
575
571t
rule A
570
rule C
571g
571p
275
271t
270
271g
271p

FIG. 3



272g
Africa
S. America
272g
2013
all five
appliances
272p
geographic
dimension
671g
product
dimension
671p
272t
674a
2007
675
time
dimension
671t
670a
574a
575
rule A
570
571t
571g
571p

FIG. 4A

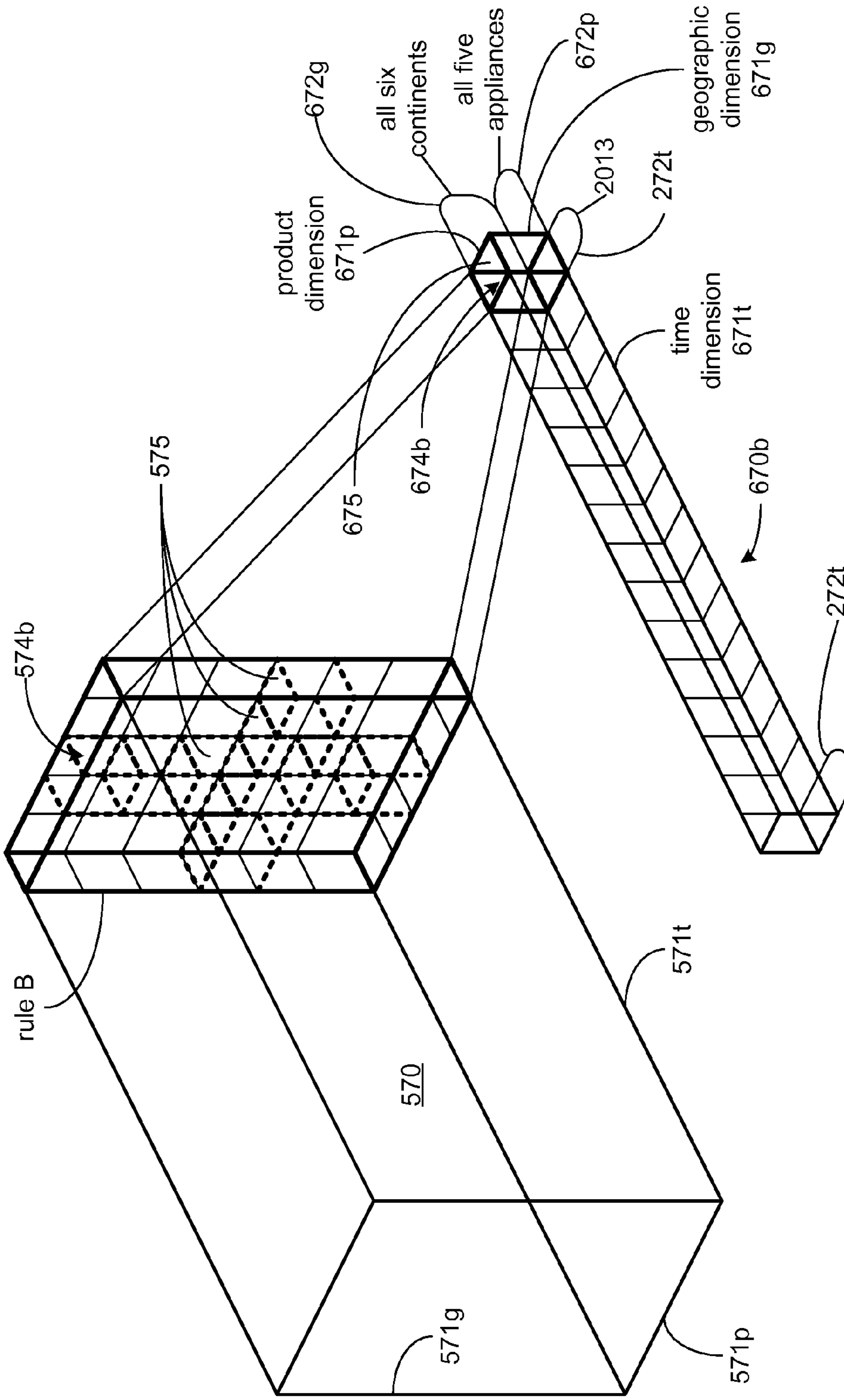

672g
all six continents
all five appliances
672p
geographic dimension 671g
2013
272t
product dimension 671p
time dimension 671t
575
675
674b
670b
574b
272t
2000
rule B
570
571t
571g
571p

FIG. 4B

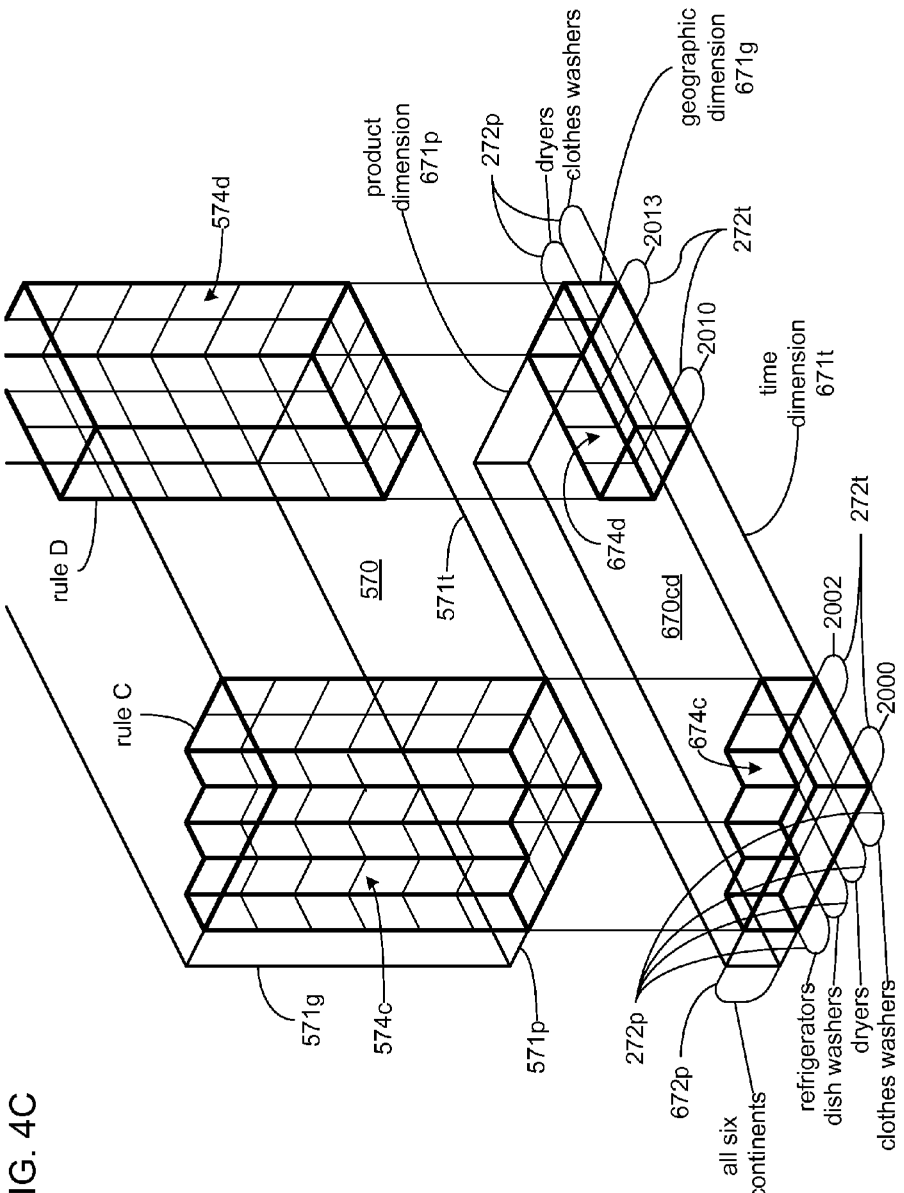
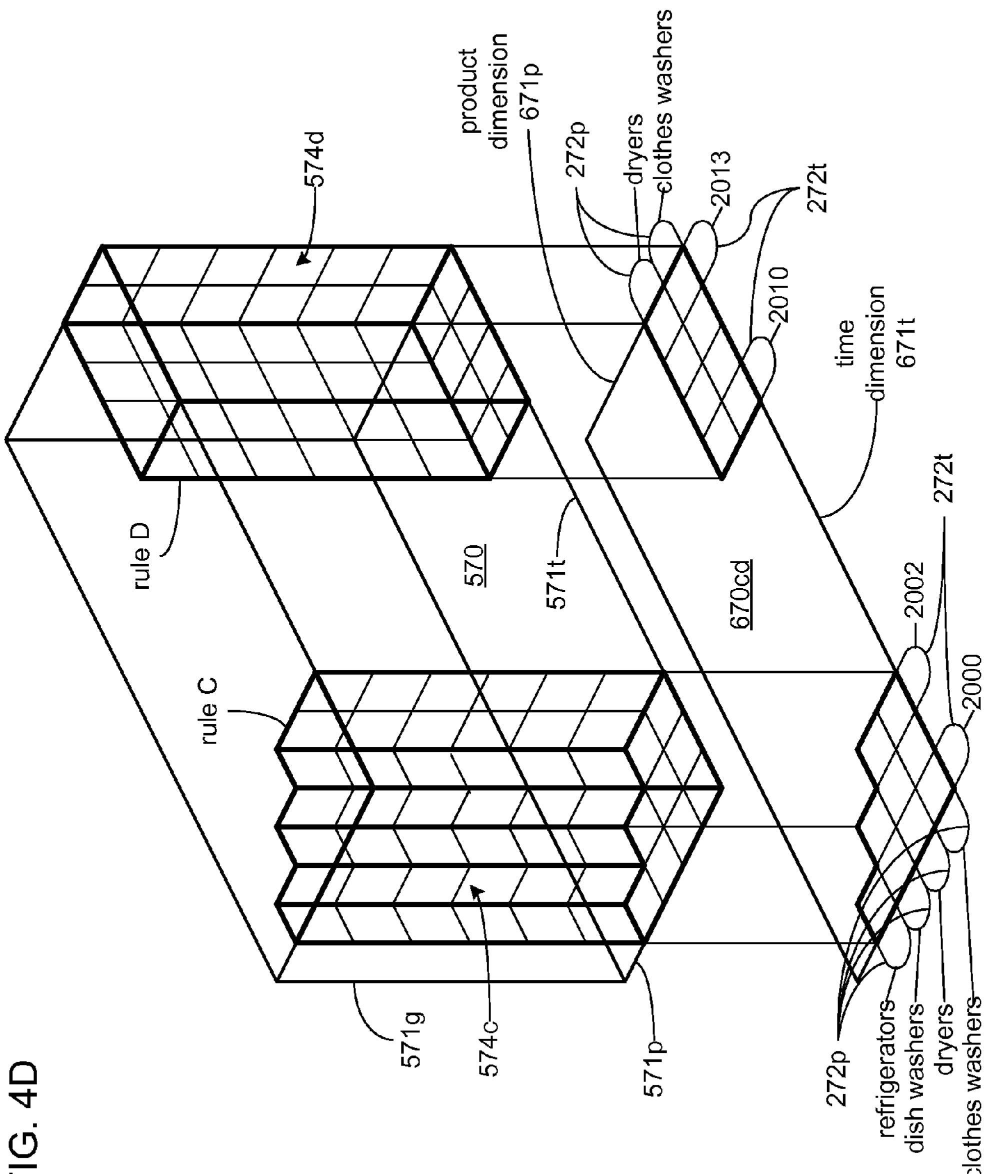
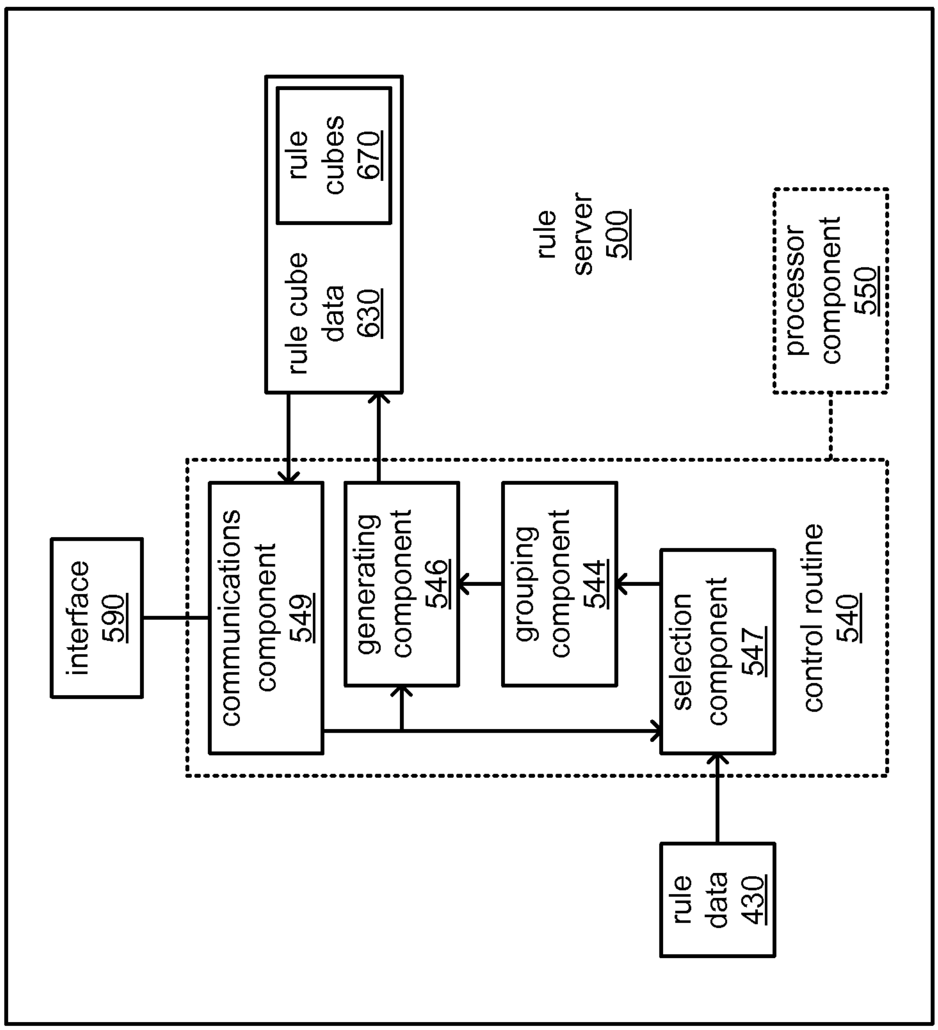

574d
rule D
570
571t
rule C
574c
571g
571p
product dimension 671p
272p
dryers
clothes washers
geographic dimension 671g
2013
272t
2010
time dimension 671t
674d
670cd
2002
272t
674c
2000
272p
672p
all six continents
refrigerators
dish washers
dryers
clothes washers

FIG. 4C

FIG. 4D

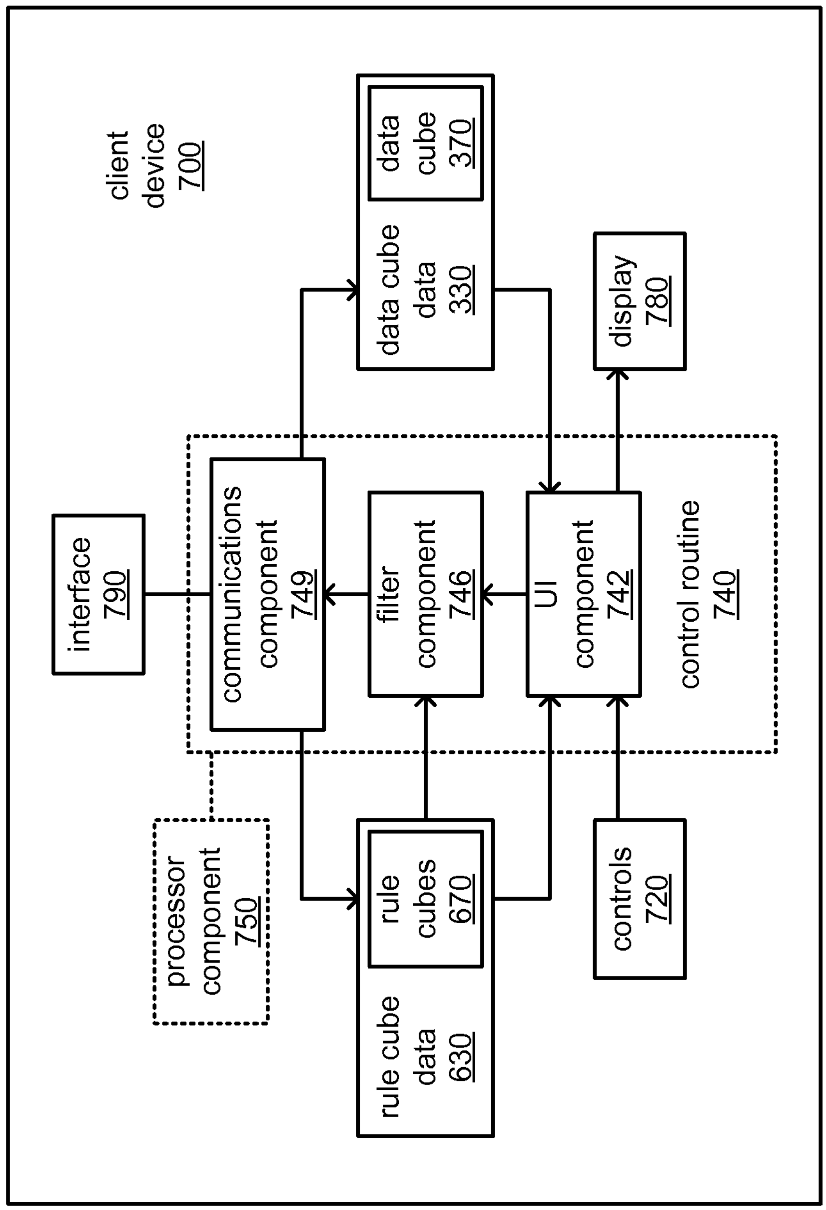


574d
product dimension 671p
272p
dryers
clothes washers
2013
272t
2010
time dimension 671t
rule D
570
571t
670cd
272t
2002
2000
rule C
571g
574c
571p
272p
refrigerators
dish washers
dryers
clothes washers


rule cube data 630
rule cubes 670
rule server 500
processor component 550
interface 590
communications component 549
generating component 546
grouping component 544
selection component 547
control routine 540
rule data 430

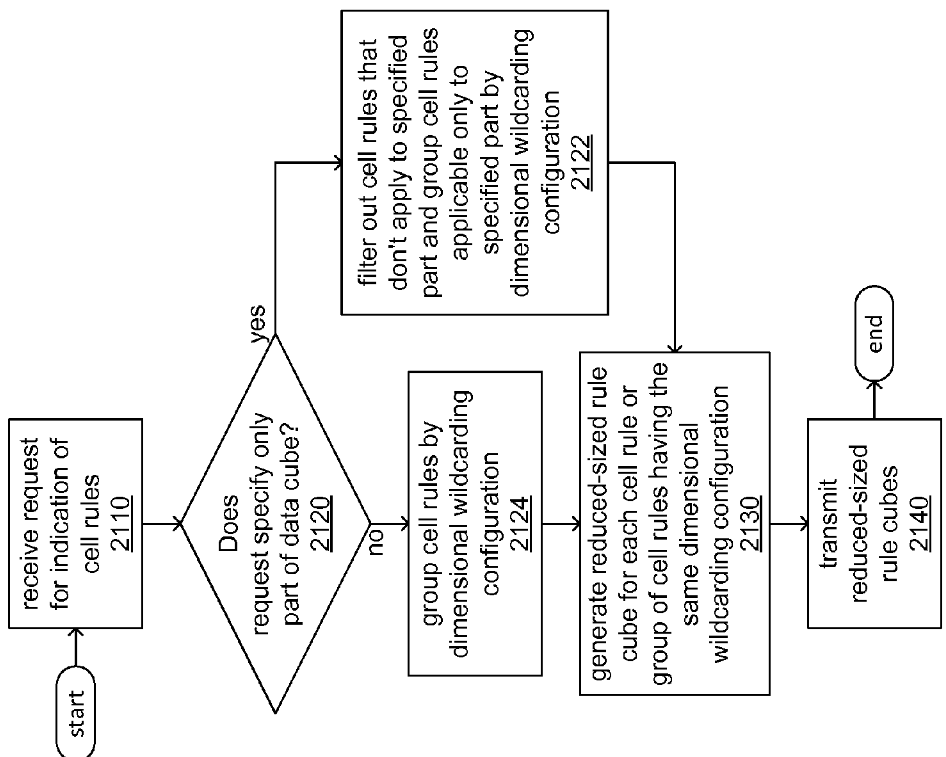
1000

FIG. 5


client device 700
data cube data 330
data cube 370
display 780
interface 790
communications component 749
filter component 746
UI component 742
control routine 740
processor component 750
rule cube data 630
rule cubes 670
controls 720

1000

FIG. 6


start
receive request for indication of cell rules 2110
Does request specify only part of data cube? 2120
yes
no
filter out cell rules that don't apply to specified part and group cell rules applicable only to specified part by dimensional wildcarding configuration 2122
group cell rules by dimensional wildcarding configuration 2124
generate reduced-sized rule cube for each cell rule or group of cell rules having the same dimensional wildcarding configuration 2130
transmit reduced-sized rule cubes 2140
end

2100

FIG. 7

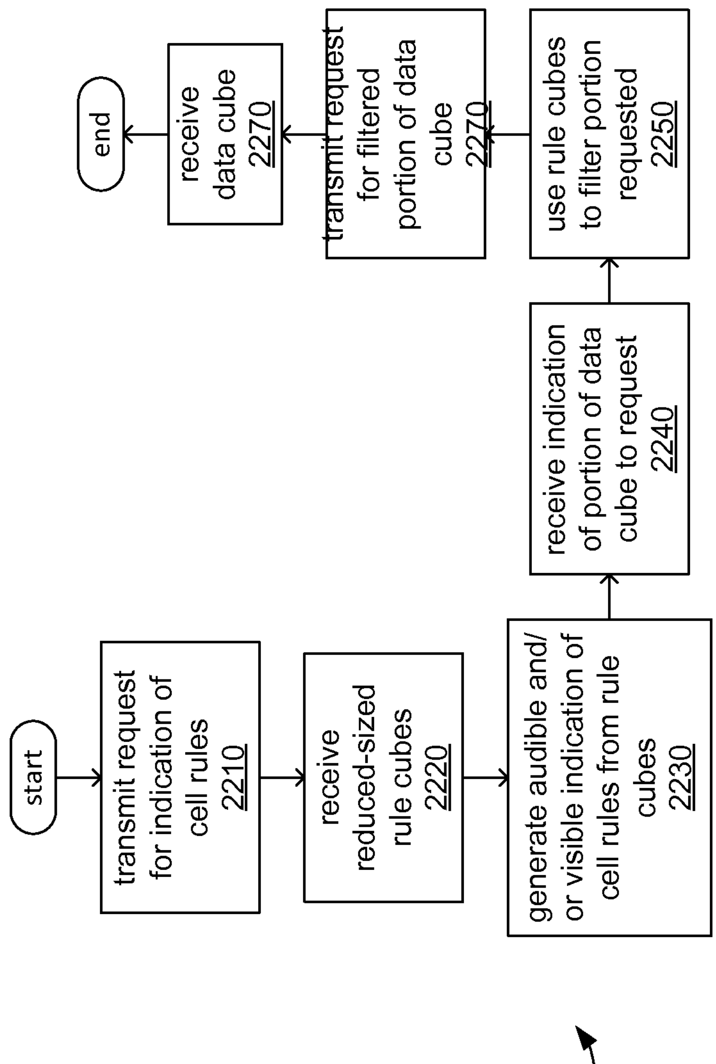

start
transmit request for indication of cell rules 2210
receive reduced-sized rule cubes 2220
generate audible and/ or visible indication of cell rules from rule cubes 2230
receive indication of portion of data cube to request 2240
use rule cubes to filter portion requested 2250
transmit request for filtered portion of data cube 2270
receive data cube 2270
end
2200

FIG. 8

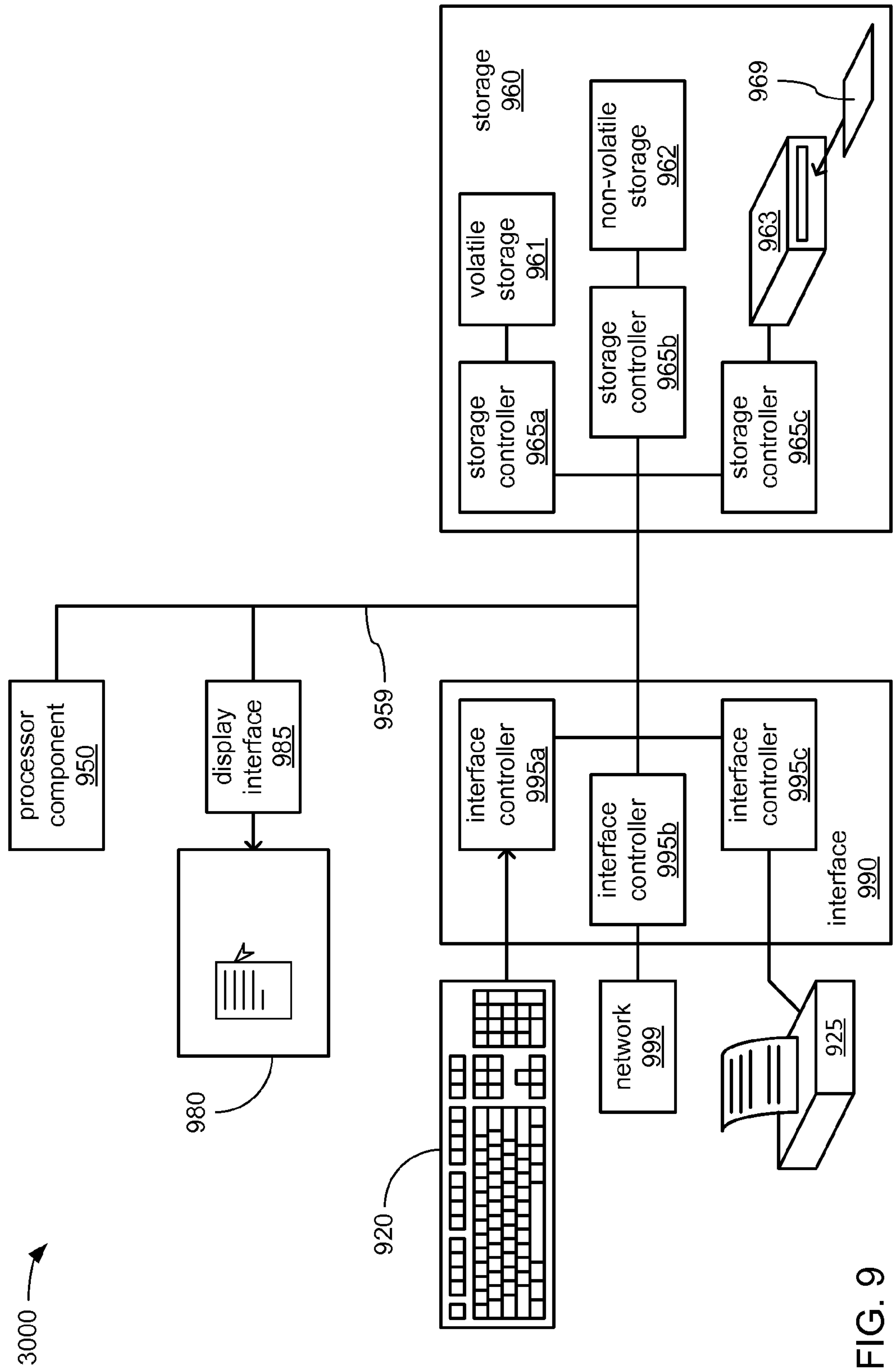

3000
processor component 950
display interface 985
959
980
920
storage 960
volatile storage 961
non-volatile storage 962
963
969
storage controller 965a
storage controller 965b
storage controller 965c
interface 990
interface controller 995a
interface controller 995b
interface controller 995c
network 999
925

FIG. 9

METHOD TO REDUCE LARGE OLAP CUBE SIZE USING CELL SELECTION RULES

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of priority under 35 U.S.C. §119(e) to U.S. Provisional Application Ser. No. 61/779,387, entitled "A METHOD TO REDUCE LARGE ONLINE ANALYTICAL PROCESSING CUBE SIZE USING CELL SELECTION RULES," filed Mar. 13, 2013, the disclosure of which is incorporated herein by reference.

BACKGROUND

Multi-dimensional data cubes employ a multi-dimensional indexing scheme to organize large quantities of detailed data. Such detailed data may be associated with any of a variety of subjects, including inventories, sales, manufacturing output, census data, data collected from scientific experiments, social networking statistics, etc. Cells within such data cubes often contain aggregated data (also commonly referred to as "measures") derived from more detailed data and/or pointers to such detailed data. Often accompanying a data cube is a rule cube having the same size and dimensions as the data cube. There cells within such rule cubes often exist in a one-to-one correspondence with the cells of the data cube, and contain indications of cell rules defining restrictions on access to the corresponding cells of the data cube. Since their inception, data cubes have come to be used to organize increasingly larger quantities of data with ever increasing numbers of dimensions. As a result, the size of the data structures used to represent both the data cubes and corresponding rule cubes have begun to exceed various limitations imposed in various computing devices.

SUMMARY

The following presents a simplified summary in order to provide a basic understanding of some novel embodiments described herein. This summary is not an extensive overview, and it is not intended to identify key/critical elements or to delineate the scope thereof. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

A computer-program product tangibly embodied in a non-transitory machine-readable storage medium, the computer-program product including instructions operable to cause a computing device to perform operations including select a first cell rule applicable to a data cube to include in a rule cube associated with the data cube based on applicability of the first cell rule to a selected portion of the data cube; analyze the first cell rule to identify at least one dimension of the data cube that is wildcarded in a first specification of the first cell rule of cells of the data cube that are subject to the first cell rule; and generate the rule cube indicating applicability of the first cell rule to the selected portion of the data cube, wherein a cell of the rule cube corresponds to multiple cells of the data cube, and wherein at least one dimension of the rule cube that corresponds to the at least one dimension of the data cube is reduced in length in comparison to a length of the at least one dimension of the data cube.

A computer-implemented method comprising selecting, on a computing device, a first cell rule applicable to a data cube to include in a rule cube based on applicability of the first cell rule to a selected portion of the data cube; analyzing, on the computing device, the first cell rule to identify at least one dimension of the data cube that is wildcarded in a first specification of the first cell rule of cells of the data cube that are subject to the first cell rule; and generating, on the computing device, the rule cube indicating applicability of the first cell rule to the selected portion of the data cube, wherein a cell of the rule cube corresponds to multiple cells of the data cube, and wherein at least one dimension of the rule cube that corresponds to the at least one dimension of the data cube is reduced in length in comparison to a length of the at least one dimension of the data cube.

An apparatus comprising a processor component, a selection component for execution by the processor component to select a first cell rule applicable to a data cube based on applicability of the first cell rule to a selected portion of the data cube, and a generating component. The generating component is for execution by the processor component to analyze the first cell rule to identify at least one dimension of the data cube that is wildcarded in a first specification of the first cell rule of cells of the data cube that are subject to the first cell rule; and generate a rule cube indicating applicability of the first cell rule to the selected portion of the data cube, wherein a cell of the rule cube corresponds to multiple cells of the data cube, and wherein at least one dimension of the rule cube that corresponds to the at least one dimension of the data cube is reduced in length in comparison to a length of the at least one dimension of the data cube.

To the accomplishment of the foregoing and related ends, certain illustrative aspects are described herein in connection with the following description and the annexed drawings. These aspects are indicative of the various ways in which the principles disclosed herein can be practiced and all aspects and equivalents thereof are intended to be within the scope of the claimed subject matter. Other features will become apparent from the following detailed description when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example of an online analytical processing system.

FIG. **2** illustrates an example of a full data cube.

FIG. **3** illustrates an example of correspondence between a full data cube and a full rule cube.

FIGS. **4**A, **4**B, **4**C and **4**D each illustrate an example of a reduced-sized rule cube indicating at least one rule applicable to a full data cube.

FIGS. **5** and **6** illustrate examples of operating environments for portions of an online analytical processing system.

FIG. **7** illustrates an example of a first logic flow.

FIG. **8** illustrates an example of a second logic flow.

FIG. **9** illustrates an example of a processing architecture.

DETAILED DESCRIPTION

Various embodiments are generally directed to techniques for supporting the provision of a data cube to a client device by providing the client device with one or more reduced-size rule cubes indicating data cube cell rules. Such provision of reduced-size rule cubes may be in response to a request from the client device for an indication of those cell rules prior to requesting the data cube. The one or more reduced-size rule cubes may be provided to the client device in lieu of a single full-size rule cube that may be too large to be practical or possible to generate and/or transmit to the client device. In some embodiments, the one or more reduced-size rule cubes may also be employed in generating the data cube to enable selective instantiation of cells of the data cube.

As familiar to those skilled in the art, a data cube is a multi-dimensional data structure in which locations along each of the dimensions are used in combination as a multi-dimensional indexing scheme to specify a location within the volume of the data cube at which a cell may be instantiated to store data and/or a pointer to data. Each dimension is divided into "members" that serve as specifiable locations along each dimension, and the members may be numeric values, names of places or thing, proper names of persons, etc. Thus, the act of specifying a location along one of the dimensions entails specifying the member at that location along that dimension. A location within the volume of a data cube at which a cell may be instantiated is typically referred to as a "crossing," and a crossing is identified by specifying the members that indicate its location along each of the dimensions. A piece of data stored within an instantiated cell of a data cube is typically referred to as a "measure," and is often a piece of aggregated data that represents a sum, average or other combinatorial value derived from other more detailed data stored in one or more other data structures. A pointer stored within a cell of a data cube is typically a pointer to data maintained in another data structure.

A cell of a data cube may include both a "measure" made up of an aggregated data value derived from more detailed data stored in another data structure, and a pointer to that more detailed data in that other data structure. This inclusion of both a measure and a pointer to the data from which the measure was derived may be used to enable "drilling down" into the more detailed data behind the aggregated data value of the measure. It is through this direct provision of aggregated data and the provision of access via a pointer to more detailed data associated therewith in each cell that enables a data cube can be employed to organize large quantities of detailed data. The multi-dimensional indexing scheme enables easier access to both the aggregated data and the pointers, thereby enabling easier access to and comprehension of aspects of large quantities of data.

A data cube may be accompanied by a rule cube. The rule cube is another multi-dimensional structure of the same dimensions and employing the same multi-dimensional indexing scheme to specify crossings at which cells may be instantiated to store an indication of one or more cell rules. A cell rule may define the degree of available access to a corresponding cell of the data cube. For example, a rule cube may be created to specify conditions under which the contents of one or more cells of its corresponding data cube (e.g., measures and/or pointers) may be accessed by a particular client device and/or a particular operator of a client device. Alternatively or additionally, a cell rule may define the manner in which a measure may be used in the performance of a calculation or other processing operation. For example, a rule cube may be created to specify conditions under which a measure may be used as an input to a calculation involving multiple neighboring cells (sometimes referred to as a "stencil" calculation) and/or the conditions under which a measure may be modified by such a calculation (e.g., minimum and/or maximum limits of a final value, a limit on a degree of change, etc.).

Both data cubes and rule cubes are typically represented in the storage of a computing device as a data structure (e.g., an array) that typically employs a flat (e.g., one-dimensional) integer-based indexing scheme. Such a data structure includes an indication of the mapping of its flat index to the multi-dimensional indexing scheme of the data or rule cube it represents, and it is not uncommon for that mapping to be identical between corresponding rule and data cubes, since they share a common multi-dimensional indexing scheme. Unfortunately, as the use of data cubes to organize data has increased, so has the size and number of dimensions of typical data cubes and their corresponding rule cubes. As a result, difficulties have begun to be encountered in simply instantiating a full data or rule cube as the growing size and number of dimensions has begun to exceed what can be represented with typical flat-indexed data structures in many computing devices. By way of example, the quantity of crossings of typical data and/or rule cubes has begun to exceed the maximum quantity of integers able to be represented with binary-coded integers (often referred to as "MAXINT") in many typical computing devices. Even where a computing device is still able to instantiate a full data or rule cube, the growing size and number of dimensions also results in a prohibitive consumption of available data bandwidth in typical networks to transmit that full data or rule cube.

To address this, at least with regard to rule cubes, the instantiation and transmission of a full rule cube corresponding to a full data cube may be avoided, and one or more reduced-size rule cubes may be instantiated and transmitted, instead. More precisely, generation of a single full-sized rule cube incorporating cells in which are stored indications of rules applied to individual corresponding cells of a corresponding full-sized data cube is avoided. Instead, each cell rule is analyzed to determine its configuration of "wildcarded" versus "non-wildcarded" dimensions. Rules having the same dimensional wildcarding configuration are combined, and a reduced-sized cube representing each such combination of rules is generated. In each such reduced-sized cube, the wildcarded dimensions are generated to have a reduced length. This reduced length may be a length of one member in some embodiments, or this reduced length be a zero length such that a wildcarded dimension is omitted. Such reductions in length of wildcarded dimensions greatly reduce the number of possible crossings within the volume of each such reduced-sized cube, thereby reducing the quantity of integers required to implement a flat index to represent it with a data structure.

One or more of such reduced-sized rule cubes may be transmitted to a client device in response to a request received therefrom for an indication of the cell rules applicable to the data cube to which the reduced-sized rule cubes correspond. Alternatively or additionally, such reduced-sized rule cubes may be employed in generating a version of the data cube intended to be provided to the client device in which cells of the data cube are selectively instantiated based on whether the rules indicate that the client device is to have access to those cells.

With general reference to notations and nomenclature used herein, portions of the detailed description which follows may be presented in terms of program procedures executed on a computer or network of computers. These procedural descriptions and representations are used by those skilled in the art to most effectively convey the substance of their work to others skilled in the art. A procedure is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. These operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical, magnetic or optical communications capable of being stored, transferred, combined, compared, and otherwise manipulated. It proves convenient at times, principally for reasons of common usage, to refer to what is communicated as bits, values, elements, symbols, characters, terms, numbers, or the like. It should be noted, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to those quantities.

Further, these manipulations are often referred to in terms, such as adding or comparing, which are commonly associated with mental operations performed by a human operator. However, no such capability of a human operator is necessary, or desirable in most cases, in any of the operations described herein that form part of one or more embodiments. Rather, these operations are machine operations. Useful machines for performing operations of various embodiments include general purpose digital computers as selectively activated or configured by a computer program stored within that is written in accordance with the teachings herein, and/or include apparatus specially constructed for the required purpose. Various embodiments also relate to apparatus or systems for performing these operations. These apparatus may be specially constructed for the required purpose or may include a general purpose computer. The required structure for a variety of these machines will appear from the description given.

Reference is now made to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding thereof. It may be evident, however, that the novel embodiments can be practiced without these specific details. In other instances, well known structures and devices are shown in block diagram form in order to facilitate a description thereof. The intention is to cover all modifications, equivalents, and alternatives within the scope of the claims.

FIG. **1** illustrates a block diagram of an example embodiment of an online analytical processing (OLAP) system **1000** incorporating one or more data servers **100***a-x*, an OLAP server **300**, a rule server **500** and/or a client device **700**. Each of these computing devices may be any of a variety of types of computing device, including without limitation, a desktop computer system, a data entry terminal, a laptop computer, a netbook computer, a tablet computer, a handheld personal data assistant, a smartphone, a digital camera, a body-worn computing device incorporated into clothing, a computing device integrated into a vehicle (e.g., a car, a bicycle, a wheelchair, etc.), a server, a cluster of servers, a server farm, etc. Embodiments are not limited in this context.

As depicted, these computing devices **100***a-x*, **300**, **500** and **700** exchange communications conveying data associated with large data and/or rule cubes through a network **999**. However, one or more of the computing devices **100***a-x*, **300**, **500** and/or **700** may exchange communications entirely unrelated to data and/or rule cubes with each other and/or with still other computing devices (not shown) via the network **999**. In various embodiments, the network **999** may be a single network that may extend within a single building or other relatively limited area, a combination of connected networks that may extend a considerable distance, and/or may include the Internet. Thus, the network **999** may be based on any of a variety (or combination) of communications technologies by which communications may be effected, including without limitation, wired technologies employing electrically and/or optically conductive cabling, and wireless technologies employing infrared, radio frequency or other forms of wireless transmission.

The one or more data servers **100***a-x* store raw data **130** from which a data cube may be generated by the OLAP server **300**. The OLAP server **300** may provide that data cube to the client device **700** in response to a request from the client device **700** for a data cube. However, before the client device **700** requests a data cube from the OLAP server **300**, the client device **700** may request an indication of cell rules applicable to that data cube from the rule server **500**.

In response to this request, the rule server **500** may transmit one or more rule cubes **670** to the client device **700**. Each of the rule cubes **670** may provide an indication of one or more cell rules applicable to the data cube to be provided to the client device **700** by the OLAP server **300**. As will be explained in greater detail, each of the rule cubes **670** is a reduced-sized rule cube inasmuch as each of the rule cubes **670** is not as large, at least in its dimensional volume, as a full rule cube providing indications of all of the cell rules would be. Indeed, all of the rule cubes **670**, taken together, occupy less storage space and use less data bandwidth in being transmitted than would a full rule cube providing indications of all of the cell rules for which the rule cubes **670** provide indications. In other words, the rule cubes **670** provide a more compact indication of those cell rules.

Upon receiving the rule cubes **670**, the client device **700** may employ those indications of the cell rules to control the generation of its request to the OLAP server **300** for a data cube in a manner that limits the size and/or dimensions of the data cube it requests to tend to include cells storing measures and/or pointers that the client device **700** will be allowed to use for the purpose for which the request is made in light of the cell rules. For example, the client device **700** may employ those indications of the cell rules to refrain from requesting portions including cells to which the client device **700** is not permitted access or to which the client device **700** is permitted read-only access. Alternatively or additionally, the client device **700** may employ those indications of the cell rules to refrain from requesting portions including cells subject to limits on the manner in which their measures may be modified during the performance of a calculation. In this way, the client device **700** refrains from requesting a full data cube from the OLAP server **300** that would include crossings at which there may be cells that the client device **700** is not permitted to use in a manner that defeats the purpose for which the client makes the request. As a result, the OLAP server **300** is not requested to expend processing, storage and/or network communications resources generating and/or transmitting a large data cube incorporating many crossings for cells that the client device **700** is barred from accessing.

In an alternative embodiment, the client device **700** may have already received or otherwise been provide access to a data cube, and may request an indication of cell rules applicable to that data cube to enable more efficient use of it. By way of example, the comparatively smaller size of each of the rule cubes **670** would enable the contents of their cells to be accessed more quickly than the contents of the cells of the data cube. Thus, the client device **700** may precede accesses to each cell of the data cube with an access to a corresponding cell of one or more of the rule cubes **670** to determine whether an intended access to the cell of the data cube is permitted and/or is subject to a limit concerning altering what is stored there.

Regardless of what use the client device **700** may make of the cell rules indicated by the rule cubes **670**, the client device **700** analyzes each of the rule cubes **670** to determine what the cell rules are and which data cube cells they apply to. A cell of a data cube may be subject to no cell rules as a result of none of the rule cubes having a corresponding cell that stores an indication of a rule. Alternatively, a cell of a data cube may be subject to a single cell rule as a result of one of the rule cubes having a corresponding cell that stores an indication of that single cell rule. As still another alternative, a cell of a data cube may be subject to multiple cell rules as a result of more than one rule cube having a corresponding cell that stores an indication of one of those cell rules.

It should be noted that despite the specific depiction and discussion herein of each of the computing devices **300**, **500** and **700** performing separate and distinct functions, embodiments are possible in which the functions of two or more of these computing devices and/or servers are performed by a single computing device. By way of example, in some embodiments, the OLAP server **300** and the rule server **500** may be combined into a single server that generates and/or transmits both data cube data representing one or more data cubes and rule cube data representing one or more rule cubes. By way of another example, in other embodiments, at least a portion of the functions performed by the client device **700** may be performed as a virtual machine implemented within one of the OLAP server **300** or the rule server **500**. In such embodiments, the client device **700** may be implemented as a "dumb terminal" or other type of computing device providing remote access to the virtual machine.

In some embodiments, the rule server **500** may additionally provide the rule cubes **670** to the OLAP server **300** for use in controlling the instantiation of cells of the data cube in response to requests for a data cube, such as the request for a data cube from the client device **700**. Like the client device **700**, the OLAP server **300** may analyze each of the rule cubes **670** to determine, for each cell of a data cube, whether it is subject to one or more cell rules and what the one or more cell rules are. More precisely, the OLAP server **300** may employ the indications of the cell rules provided in more compact form by the rule cubes **670** to control what cells to instantiate in a data cube generated to satisfy such a request.

In various embodiments, each of the one or more data servers **100***a-x* incorporates one or more of a processor component **150**, a storage **160** and an interface **190** to couple each of the one or more data servers **100***a-x* to the network **999**. The storage **160** of each of the one or more data servers **100***a-x* stores a control routine **140** and at least a portion of the raw data **130**. The control routine **140** incorporates a sequence of instructions operative on the processor component **150** to implement logic to perform various functions.

In executing the control routine **140**, the processor component **150** of each of the one or more data servers **100***a-x* may operate the interface **190** to transmit at least a portion of the raw data **130** to the OLAP server **300**. The processor component **150** may do so in response to one or more requests received from the OLAP server **300** for at least a portion of the raw data **130**. The raw data **130** may include data on any of a variety of subjects, including and not limited to, manufacturing, inventory, provision of services, financial accounts, financial or other types of transactions, statistics concerning use of services, patient medical data, academic data, customer data, data gathered during scientific experiments, etc.

In various embodiments, the OLAP server **300** incorporates one or more of a processor component **350**, a storage **360** and an interface **390** to couple the OLAP server **300** to the network **999**. The storage **360** stores one or more of a control routine **340**, at least a portion of the raw data **130**, data cube data **230** representing a full data cube **270**, and data cube data **330** representing a data cube **370**. The control routine **340** incorporates a sequence of instructions operative on the processor component **350** to implement logic to perform various functions.

In executing the control routine **340**, the processor component **350** of the OLAP server **300** may operate the interface **390** to receive at least a portion of the raw data **130** from one or more of the data servers **100***a-x*. In some embodiments, at least one of the data servers **100***a-x* may generate whatever portion of the raw data **130** is provided to the OLAP server **300** from pieces of the raw data **130** received from others of the data servers **100***a-x*. In other embodiments, the OLAP server **300** may receive pieces of the raw data **130** from one or more of the data servers **100***a-x*, and the processor component **350** may combine those pieces to generate at least a portion of the raw data **130** stored within the storage **360**.

Following such receipt and/or generation of at least a portion of the raw data **130**, the processor component **350** may form a data cube from at least a portion of the raw data **130**. In so doing, the processor component **350** may generate aggregated pieces of data to be included as measures within cells of a cube from more detailed data within the raw data **130** (e.g., a summation, average, weighted average, etc. of the more detailed data). Alternatively or additionally, the processor component **350** may derive pointers to the more detailed data for inclusion as pointers within cells of a cube.

FIG. **2** illustrates an example embodiment of the full data cube **270** that may be generated by the processor component from at least a portion of the raw data **130**. It should be noted that, for sake of simplicity in discussion and understanding, the full data cube **270** is a deliberately simple example having only three dimensions **271***g*, **271***p* and **271***t*, and a relatively small volume capable of including a relatively small quantity of cells **275**. It is envisioned that more realistic embodiments of the full data cube **270** would be far larger and/or include a far greater number of dimensions.

The full data cube **270** organizes aggregated data derived from the raw data **130** concerning sales by a company of various home appliances over a period of years in various continents. The cells **275** may contain measures of concerning those sales over periods of entire years and across entire continents, while the raw data **130** may contain indications of specific sales of specific appliances on specific dates in specific store locations. In this example, the full data cube **270** serves as a mechanism to organize the raw data **130** of those sales of stoves, refrigerators, dish washers, dryers and clothes washers over the years 2000 through 2013 in Africa, South America, Australia, Europe, Asia and North America in a manner enabling easier comprehension and access.

In various embodiments, the data cube data **230** may have any of a variety of types of data structure in which flat indexing may be employed, including tables, arrays, etc. The processor component generates entries in that data structure for each cell **275** that is instantiated at a crossing within the full data cube **270**. This data structure of the data cube data **230** includes an indication of the mapping of its flat indexing scheme to the multi-dimensional indexing scheme of the full data cube **270** to enable access to a particular one of the entries. The data cube data **230** may also include metadata specifying the dimensions **271***g*, **271***p* and **271***t*. Alternatively or additionally, the data cube data **230** may also include metadata specifying the members **272***g*, **272***p* and **272***t* along corresponding ones of the dimensions **271***g*, **271***p* and **271***t*.

As depicted, the geographic dimension **271***g* provides an index in one dimension organized by continent such that Africa, South America, Australia, Europe, Asia and North America are each a member **272***g* of the geographic dimension **271***g*. The product dimension **271***p* provides an index in another dimension organized by product such that stoves, refrigerators, dish washers, dryers and clothes washers are each a member **272***p* of the product dimension **271***p*. The time dimension **271***t* provides an index in still another dimension organized by sequential years such that each of the years 2000 through 2013 are each a member **272***t* of the time dimension **271***t*. The act of accessing a cell **275** of the full data cube **270** at a particular crossing entails resolving the location of that crossing along the dimensions **271***g*, **271***p* and **271***t* as indicated by specifying particular ones of the members **272***g*, **272***p* and **272***t*, respectively, to a flat index used to access the entry in the data structure of the data cube data **230** that corresponds to the cell **275** at that crossing. With the corresponding entry found, the act of storing data and/or a pointer in that cell **275** is effected by storing that data and/or pointer in that corresponding entry.

As depicted, there are particular products that have been sold in particular continents by the company that have changed over time. For example, from 2000 to 2003, the company sold stoves, refrigerators, dish washers, dryers and clothes washers only in North America. The company then added sales of all five products in Asia in 2004, added sales of all five products in Europe in 2005, and then added sales of all five products in Australia, South America and Africa in 2006. However, the company then retreated from selling any of its products in South America or Africa in 2007, and then abandoned selling dryers and clothes washers in any continent in 2010. As a result of these changes in what products have been sold in what places over time, there are numerous crossings within the full data cube **270** at which cells **275** could be instantiated, but would not be used as there is no data associated with those crossings. By way of example, no appliances of any type were ever sold in Africa in 2013, and therefore, there is no data associated with any of the crossings for any appliance in Africa in 2013.

This characteristic of many data cubes used to organize real world data in which no data exists (or will ever exist) for a subset of the crossings is referred to as "sparsity." Indeed, in data cubes associated with real word data, it is not uncommon for more than half of the crossings to have no data associated with them such that any cells instantiated at those crossings will not contain either measures or pointers. As depicted, there are portions of the volume of the full data cube **270** that include crossings at which cells **275** are instantiated for which data does exist that could be stored directly in those cells **275** as measures and/or that could be pointed to with pointers stored in those cells **275**. However, as also depicted, there are portions of the volume of the full data cube **270** that include crossings at which cells **275** could also be instantiated, but for which no data exists.

Again, the depicted example of the full data cube **270** in FIG. **2** is a deliberately simple example selected for purposes of illustration and understanding. Again, it is envisioned that a real world example of the full data cube **270** could be far larger and/or incorporate more dimensions. Indeed, limitations of the OLAP server **300** may make it prohibitively difficult to instantiate the full data cube **270**, and this is reflected in the depiction of the data cube data **230** in FIG. **1** with dotted lines. As will be explained in greater detail, such difficulties in instantiating the full data cube **270** may be addressed by providing the OLAP server with indications of cell rules from the rule server **500** to enable the OLAP server to selectively instantiate cells of a data cube.

Returning to FIG. **1**, in various embodiments, the rule server **500** incorporates one or more of a processor component **550**, a storage **560** and an interface **590** to couple the rule server **500** to the network **999**. The storage **560** stores one or more of a control routine **540**, rules data **430**, rule cube data **530** representing a full rule cube **570**, and rule cube data **630** representing one or more reduced-sized rule cubes **670**. The control routine **540** incorporates a sequence of instructions operative on the processor component **550** to implement logic to perform various functions.

In executing the control routine **540**, the processor component **550** may generate at least one rule cube from the rule data **430**. The rule data **430** incorporates indications of one or more cell rules associated with the raw data **130**, and accordingly, with a data cube (e.g., the full data cube **270**) generated therefrom. The processor component **550** may so generate one or more rule cubes and then transmit the one or more rule cubes to another computing device (e.g., the OLAP server **300** or the client device **700**) as an approach to conveying an indication of what cell rules apply to which data cells of a data cube.

FIG. **3** illustrates an example embodiment of the full rule cube **570** that may be generated by the processor component **550** from the rule data **430**. As depicted, the full rule cube **570** corresponds to the full data cube **270** inasmuch as the full rule cube **570** has three dimensions **571***g*, **571***p* and **571***t* that correspond in length to the dimensions **271***g*, **271***p* and **271***t*, respectively. Thus, the full rule cube **570** encompasses the same number of crossings as the full data cube **270** and employs an identical multi-dimensional indexing scheme as the full data cube **270**. This creates a one-to-one correspondence between cells **275** of the full data cube **270** containing measures and/or pointers and cells **575** of the full rule cube **570** containing indications of one or more cell rules concerning their corresponding cells of the full data cube **270**. Further, the full rule cube **570** and full data cube **270** may also employ the same mapping of this multi-dimensional indexing scheme employed by both to a flat indexing scheme also employed by both. Indeed, the OLAP server **300** and the rule server **500** may exchange information concerning such a mapping to ensure that both employ a common flat indexing scheme with an identical mapping to a common multi-dimensional indexing scheme.

As depicted, the full rule cube **570** incorporates indications of four cell rules labeled A through D. To enable the intersecting cube portions subjected to cell rules A, B and D to be visually distinguishable, each is depicted with a different line style. The one-to-one correspondence of cells **275** of the full data cube **270** to the cells **575** of the full rule cube **570** provides a mechanism to determine which the cells **275** of the full data cube **270** a particular cell rule applies to. Stated differently, a particular cell rule applies to a particular cell **275** of the full data cube **270** if an indication of that particular cell rule is stored in a cell **575** of the full rule cube **570** that corresponds to that particular cell **275**.

Thus, a processor component of a computing device to which the rule server **500** transmits the full rule cube **570** may determine which cells **275** of the full data cube **270** are subject to one or more access restrictions by examining corresponding cells **575** of the full rule cube **570** for indications of one or more access restrictions. However, as previously discussed, the full data cube **270** may be sufficiently large in size and/or number of dimensions that it becomes prohibitively difficult to instantiate it. Given that the corresponding full rule cube **570** is of identical dimensions encompassing an identical number of crossings, the full rule cube **570** may also be prohibitively difficult to instantiate, and this is reflected in the depiction of the rule cube data **530** representing the full rule cube **570** in FIG. **1** also with dotted lines. The full rule cube **570** may, therefore, also be prohibitively difficult to transmit to another computing device.

Each of the cell rules A through D indicated in the rule data **430** and by the full rule cube **570** may be any of a variety of rules that define limits on reading, writing or otherwise accessing or altering either a measure or a pointer to detailed data through mathematical, bitwise logical or other operations. By way of example, a cell rule may allow reading of certain measures and/or pointers, but may limit writing or other modification of those measures and/or pointers based on any of a variety of conditions. By way of another example, an cell rule may allow only particular persons and/or computing devices to modify certain measures and/or pointers. Still other limitations are possible that are timing dependent such that specific types of access to certain measures and/or pointers is permitted only during specific times of a day and/or during specific days of a week. Still other types of cell rules will occur to those skilled in the art.

FIGS. **4**A-D each illustrate an example of a reduced-sized rule cube, specifically rule cubes **670***a*, **670***b* and **670***cd*. Each of the rule cubes **670***a*, **670***b* and **670***cd* are an instance of the one or more rule cubes **670** represented by the rule cube data **630**. Taken together, these reduced-sized rule cubes may be generated and transmitted to another computing device by the processor component **550** to convey indications of the cell rules A through D, instead of attempting to generate and transmit the much larger full rule cube **570** to do so. Each of FIGS. **4**A-D provides a visual comparison of the relative size of the full rule cube **570** compared to each of the rule cubes **670***a*, **670***b* and **670***cd*. As previously discussed with regard to FIG. **3**, the dimensions **571***g*, **571***p* and **571***t* of the full rule cube **570** correspond to the dimensions **271***g*, **271***p* and **271***t*, respectively, of the full data cube. In a similar manner, in each of FIGS. **4**A-C, the dimensions **571***g*, **571***p* and **571***t* of the full rule cube **570**, and the dimensions **271***g*, **271***p* and **271***t* of the full data cube **270** also correspond to the dimensions **671***g*, **671***p* and **671***t*, respectively, of each of the reduced-sized rule cubes **670***a*, **670***b* and **670***cd*. However, as becomes clear, each of the rule cubes **670***a*, **670***b* and **670***cd* is considerable smaller than the full rule cube **570**. Further, the rule cubes **670***a*, **670***b* and **670***cd*, together, are able to convey the same information as the full rule cube **570**, but in a more compact form.

Turning to FIG. **4**A, and also referring to FIG. **2**, a contrast is depicted between the manner in which the cells **275** of the full data cube **270** to which cell rule A applies are indicated by each of the full rule cube **570** and the reduced-sized rule cube **670***a*. Cell rule A applies to all cells **275** of the full data cube **270** located at crossings for any of the five appliances sold in Africa or South America during any of the years 2007 through 2013.

To provide an indication of what cells **275** of the full data cube **270** are subjected to cell rule A, all of the cells **575** of the full rule cube **570** within the depicted volume **574***a* must store an indication of cell rule A. A computing device analyzing the full rule cube **570** to determine what cells **275** of the full data cube **270** are subjected to cell rule A would analyze every cell **575** of the full rule cube **570**, and would discover that the cells **575** within the volume **574***a* store an indication of cell rule A. Given the one-to-one correspondence between the cells **575** of the full rule cube **570** and the cells **275** of the full data cube **270**, the locations of the cells **575** that store an indication of cell rule A would indicate that the cells **275** at those corresponding locations within the full data cube **270** are the ones subjected to cell rule A.

In contrast, to provide an indication of what cells of the full data cube **270** are subjected to cell rule A, only the cells **675** of the rule cube **670***a* within the depicted volume **674***a* need store an indication of cell rule A. A computing device analyzing the rule cube **670***a* to determine what cells **275** of the full data cube **270** are subjected to cell rule A could analyze every cell **675** of the rule cube **670***a*, and would discover that the cells **675** within the volume **674***a* store an indication of cell rule A. However, unlike the one-to-one correspondence of cells between the full data cube **270** and the full rule cube **570**, each cell **675** of the rule cube **670***a* corresponds to all cells **275** of the full data cube **270** that share the same location along the time dimension **271***t* and along the geographic dimension **271***g*, and regardless of their location along the product dimension **271***p*.

This one-to-many correspondence of cells arises from the fact that cell rule A is specified as applying to all of the products sold within the specified continents Africa and South America and within the specified years 2007 through 2013. Stated differently, the specification of what cells **275** of the full data cube **270** are subjected to this rule is "wildcarded" along the product dimension **271***p* as a result of there being no limitation on the application of rule A based on specific product members **272***p* along the product dimension **271***p*. As depicted this wildcarding of the product dimension **271***p* is reflected in the fact that the rule cube **670***a* is generated with its product dimension **671***p* having a reduced length of only one product member **6'72***p* that includes all of the product members **272***p* of the full data cube **270**, such that this one product member **672***p* might be regarded as a wildcard product member. In contrast to the wildcarding of the product dimension **271***p*, cell rule A is specified as applying to some of the geographic members **272***g* along the geographic dimension **271***g* of the full data cube **270**, but not to others. Similarly, cell rule A is specified as applying to some of the temporal members **272***t* along the time dimension **271***t* of the full data cube **270**, but not to others.

Thus, while there is a need to differentiate among specific temporal members **272***t* and specific geographic members **272***g* in distinguishing which cells **275** of the full data cube **270** are subject to cell rule A, there is no need to differentiate among specific product members **272***p*. In executing the control routine **500** to generate the rule cube **670***a*, the processor component **550** takes advantage of the lack of need to differentiate among product members **272***p* by generating the rule cube **670***a* to give its product dimension **671***p* a reduced length of only one member (e.g., the wildcard product member **672***p*). However, as will be explained in greater detail, other embodiments are possible in which the processor component **550** takes advantage of the lack of need to differentiate among members of a particular dimension by generating a rule cube in which that dimension is given a further reduced length of zero members.

As a result, the rule cube **670***a* is able to provide an indication of the applicability of rule A to multiple cells **275** of the full data cube **270** with the storage of an indication of rule A in only a single one of its cells **675**. In contrast, and as depicted, five of the cells **575** of the full rule cube **570** must store an indication of cell rule A to indicate the same applicability to the same multiple cells **275** of the full data cube **270**. More generally, the overall smaller size of the rule cube **670***a* (1×6×14 members in size) versus the full rule cube **570** (5×6×14 members in size) results in the data structure representing the rule cube **670***a* in the rule cube data **630** being considerably smaller than the data structure representing the full rule cube **570** in the rule cube data **530**. Thus, the representation of the rule cube **670***a* is considerably smaller, is accordingly far less likely to be prohibitively difficult to generate and store within the storage **560** of the rule server **500**, and is further less likely to be prohibitively difficult to transmit to another computing device.

Turning to FIG. **4**B, and also referring to FIG. **2**, a similar contrast is depicted between the manner in which the cells **275** of the full data cube **270** to which rule B applies are indicated by each of the full rule cube **570** and the reduced-sized rule cube **670***b*. Cell rule B applies to all cells **275** of the full data cube **270** located at crossings for any of the five appliances sold in any of the six continents during the year 2013.

To provide an indication of what cells **275** of the full data cube **270** are subjected to cell rule B, all of the cells **575** of the full rule cube **570** within the depicted volume **574***b* must store an indication of rule B. A computing device analyzing the full rule cube **570** to determine what cells **275** of the full data cube **270** are subjected to rule B could analyze every cell **575** of the full rule cube **570**, and would discover that the cells **575** within the volume **574***b* store an indication of cell rule B. Again, the locations of the cells **575** that store an indication of rule B would indicate that the cells **275** at corresponding locations within the full data cube **270** are the ones subjected to cell rule B.

In contrast, to provide an indication of what cells of the full data cube **270** are subjected to cell rule B, only the single cell **675** of the rule cube **670***b* within the depicted volume **674***b* need store an indication of cell rule B. A computing device analyzing the rule cube **670***b* to determine what cells **275** of the full data cube **270** are subjected to cell rule B could analyze every cell **675** of the rule cube **670***b*, and would discover that the one cell **675** within the volume **674***b* stores an indication of cell rule B. Unlike the one-to-one correspondence of cells between the full data cube **270** and the full rule cube **570**, each cell **675** of the rule cube **670***b* corresponds to all cells **275** of the full data cube **270** that share the same location along the time dimension **271***t*, and regardless of their location along either of the geographic dimension **271**g or the product dimension **271***p*.

Not unlike the rule cube **670***a*, in the rule cube **670***b*, this one-to-many correspondence of cells arises from the fact that cell rule B is specified as applying to all of the products sold within all of the continents, with only temporal members along the time dimension **271***t* being specified. Stated differently, the specification of what cells **275** of the full data cube **270** are subjected to this rule is wildcarded along both of the geographic dimension **271**g and the product dimension **271***p* as a result of there being no limitation on the application of cell rule B based on specific product members **272***p* along the product dimension **271***p* or based on specific geographic members **272***g* along the geographic dimension **271**g.

Again, such wildcarding is reflected in the lengths of the dimensions of the rule cube **670***b*. As depicted, the wildcarding of the geographic dimension **271**g is reflected in the fact that the geographic dimension **671**g of the rule cube **670***b* has a reduced length of only one geographic member **672***g* that includes all of the geographic members **272***g* of the full data cube **270** (e.g., a wildcard geographic member). Similarly, the wildcarding of the product dimension **271***p* is reflected in the fact that the product dimension **671***p* of the rule cube **670***b* has a reduced length of only one geographic member **6'72***p* that includes all of the product members **272***p* of the full data cube **270** (e.g., a wildcard geographic member). In contrast to the wildcarding of the geographic dimension **271***g* and the product dimension **271***p*, cell rule B is specified as applying to some of the temporal members **272***t* along the time dimension **271***t* of the full data cube **270**, but not to others.

Thus, while there is a need to differentiate among specific temporal members **272***t* in distinguishing which cells **275** of the full data cube **270** are subject to cell rule B, there is no need to differentiate among specific geographic members **272***g* or specific product members **272***p*. In executing the control routine **500** to generate the rule cube **670***a*, the processor component **550** takes advantage of the lack of need to differentiate among geographic members **272***g* and product members **272***p* by generating the rule cube **670***b* to give both its geographic dimension **671**g and its product dimension **671***p* a reduced length of only one member (e.g., the wildcard geographic member **672***g* and the product member **6'72***p*, respectively). Again, however, other embodiments are possible in which the wildcarding of the geographic dimension **271***g* and the product dimension **271***p* would be reflected in reduced lengths for the geographic dimension **671**g and the product dimension **671***p* of zero members.

As a result, the rule cube **670***b* is able to provide an indication of the applicability of cell rule B to all of the cells **275** of the full data cube **270** to which it is intended to apply with the storage of an indication of cell rule B in only a single one of its cells **675**. In contrast, and as depicted, the entire volume **574***b* of five by six cells **575** of the full rule cube **570** must store an indication of cell rule B to indicate the same applicability to the same multiple cells **275** of the full data cube **270**. More generally, the overall smaller size of the rule cube **670***b* (1×1×14 members in size) versus the full rule cube **570** (5×6×14 members in size) results in the data structure representing the rule cube **670***b* in the rule cube data **630** being considerably smaller than the data structure representing the full rule cube **570** in the rule cube data **530**.

Turning to FIG. **4**C, and also referring to FIG. **2**, another example contrast is depicted between the manner in which the full rule cube **570** and a reduced-sized rule cube **670***cd* indicates applicability of cell rules. However, unlike the rule cubes **670***a* and **670***b* that each provided an indication of applicability of only one cell rule to cells **275** of the full data cube **270**, the rule cube **670***cd* provide such an indication for two rules, specifically cell rules C and D.

In some embodiments, the processor component **550**, in executing the control routine **540**, may combine indications of applicability of more than one cell rule into a single reduced-sized rule cube if those cell rules have the same dimensional wildcarding configuration. Stated differently, two or more cell rules may be combined if the combination of dimensions that are wildcarded and not wildcarded in their specifications of what cells **275** of the full data cube **270** they each apply to is the same.

By way of example, and as depicted, cell rule C applies to all cells **275** of the full data cube **270** located at crossings for clothes washers and dryers sold in any of the six continents from 2000-2002, for dishwashers sold in any of the six continents from 2000-2001, and for refrigerators sold in any of the six continents during 2000. Further, cell rule D applies to all cells **275** of the full data cube **270** located at crossings for clothes washers and dryers sold in any of the six continents from 2010 to 2013. Thus, both cell rules C and D wildcard the geographic dimension **271***g* of the full data cube **270**, but not the product dimension **271***p* and not the time dimension **271***t*.

The fact that both cell rules C and D have the same dimensional wildcard configuration enables the generation of the rule cube **670***cd* with a compact size in which its geographic dimension **671***g* has a reduced length of only one geographic member **672***g* that includes all of the geographic members **272***g* of the full data cube **270** (e.g., a wildcard geographic member). In contrast, attempting to combine one or both of cell rules C and D in the same rule cube with cell rule A would not allow for any dimension to be reduced in length to only one member, since the specification for what cells **275** of the full data cube **270** are subject to cell rule A does not wildcard the geographic dimension **271***g*.

As a result, the rule cube **670***cd* is able to provide an indication of the applicability of both cell rules C and D to all of the cells **275** of the full data cube **270** to which each is intended to apply with the storage of indications of cell rules C and D in fewer cells **675** than the number of cells **575** required to provide the same indications in the full rule cube **570**. The overall smaller size of the rule cube **670***cd* (5×1×14 members in size) versus the full rule cube **570** (5×6×14 members in size) results in the data structure representing the rule cube **670***cd* in the rule cube data **630** being considerably smaller than the data structure representing the full rule cube **570** in the rule cube data **530**.

Turning to FIG. **4**D, and also referring to FIG. **2**, an alternate example embodiment of the reduced-sized rule cube **670***cd* is presented, and in another example contrast between the manner in which the full rule cube **570** and a reduced-sized rule cube indicates applicability of cell rules. Like the example embodiment of the rule cube **670***cd* of FIG. **4**C, this alternate example embodiment of FIG. **4**D provides an indication of applicability of both cell rules C and D to cells **275** of the full data cube **270**.

Also like the rule cube **670***cd* of FIG. **4**C, geographic dimension **671***g* of the rule cube **670***cd* of FIG. **4**D is also of a reduced length. However, unlike the reduced length of one member (e.g., the wildcard geographic member **672***g*) of the geographic dimension **671***g* of the rule cube **670***cd* of FIG. **4**C, the geographic dimension **671***g* of the rule cube **670***cd* of FIG. **4**D is reduced to a length of zero members. Stated differently, the length of the geographic dimension **671***g* of the rule cube **670***cd* of FIG. **4**D is reduced to extent of being omitted by the processor component **550** in generating the rule cube **670***cd*.

Returning to FIG. **1**, the generation of multiple reduced-sized rule cubes (e.g., the rule cubes **670***a*, **670***b* and **670***cd*) may be performed in parallel. More specifically, a separate thread of processing may be allocated to the generation of each reduced-sized rule cube. In some embodiments, all of those threads may be executed by the processor component **550** or multiple ones of the processor component **550** of the rule server **500**. In other embodiments, at least a subset of those threads may be allocated to one or more other computing devices (not shown) that may be overseen and/or coordinated by the processor component **550**.

Following the generation of the reduced-sized rule cubes **670***a*, **670***b* and **670***cd*, the processor component **550** of the rule server **500** may operate the interface **590** to transmit the rule cube data **630** representing these rule cubes to the client device **700**. Again, the processor component **550** may transmit the rule cube data **630** to the client device **700** in response to a request therefrom for an indication of rules applicable to the cells **275** of the full data cube **270**. Alternatively or additionally, the processor component **550** may transmit the rule cube data **630** to the OLAP server **300** to enable the OLAP server **300** to employ the indications of rules of the rule cube data **630** in selectively instantiating cells of a data cube meant to be transmitted to the client device **700**.

Indeed, the processor component **350** of the OLAP server **300** may employ the indications of rules to enable generating a smaller data cube **370** that represents a subset of the full data cube **270**. The reduced size of the data cube **370** may be due to the lack of instantiation by the processor component **350** of cells that would contain measures and/or pointers to which the client device **700** (or a particular person using the client device **700**) is not permitted to have any access. More precisely, before instantiating each cell of the data cube **370**, the processor component **350** may analyze each of the rule cubes **670** to determine whether there is a cell rule that applies to that cell of the data cube **370** that may serve as a basis for not instantiating that cell. In some embodiments, such analysis of each of the rule cubes **670** for each cell of the data cube **370** that might be instantiated may be performed in parallel on separate threads that may be executed by the processor component **350** or multiple ones of the processor components **350**.

In various embodiments, the client device **700** incorporates one or more of a processor component **750**, a storage **760**, controls **720**, a display **780** and an interface **790** to couple the client device **700** to the network **999**. The storage **760** stores one or more of a control routine **740**, the rule cube data **630** representing the rule cubes **670**, and the data cube data **330** representing the data cube **370**. The control routine **740** incorporates a sequence of instructions operative on the processor component **750** to implement logic to perform various functions.

In executing the control routine **740**, the processor component **750** may operate the controls **720** and/or the display **780** to provide a user interface by which one or more commands may be received to request data from the OLAP server **300**. In response to receiving such input, the processor component **750** may first operate the interface **790** to transmit such a request to the rule server **500** via the network **999** for indications of what cell rules apply to the cells **275** of the full data cube **270**. As just discussed, the rule server **500** provides the client device **700** with the rule cube data **630** via the network **999**, thereby conveying the rule cubes **670** (e.g., **670***a*, **670***b* and **670***cd*) to the client device **700**.

The processor component **750** may analyze each of the rule cubes **670** to determine which cells **275** are specified by the rule cubes as subject to a cell rule indicated by one or more of the rule cubes **670**. By way of example, for a particular cell **275**, the processor component **750** may employ its location as specified by members along the geographic dimension **271***g*, the product dimension **271***p* and the time dimension **271***t* to determine the corresponding location within the rule cube **670***a*. Since the geographic dimension **271***g* is wildcarded by cell rule A of the rule cube **670***a*, all members **272***g* along the geographic dimension **271***g* are effectively included by cell rule A. As a result, where exactly the cell **275** is located along the geographic dimension **271***g* does not control whether cell rule A would apply to the cell **275**. However, since the product dimension **271***p* is not wildcarded by cell rule A, the product dimension **271***p* of the full data cube **270** and the product dimension **671***p* of the rule cube **670***a* are of the same length, and are made up of identical members. Similarly, since the time dimension **271***t* is not wildcarded by cell rule A, the time dimensions **271***t* and **671***t* are also of the same length and are also made up of identical members. Thus, the processor component **750** employs the location of the cell **275** along the product dimension **271***p* and the time dimension **271***t* of the full data cube **270** to identify the corresponding cell **675** in the rule cube **670***a*. The processor component **750** then checks the contents of that corresponding cell **675** in the rule cube **670***a* to determine whether there is an indication of at least one cell rule (e.g., cell rule A) stored therein. If there is such an indication, then the cell rule(s) indicated within that corresponding cell **675** is deemed to apply to the cell **275**.

The processor component **750** similarly determines what the corresponding cells **675** are in each of the rule cubes **670***b* and **670***cd*, and similarly checks the contents of those corresponding cells **675** in each of the rule cubes **670***b* and **670***cd* to determine whether there is an indication of a cell rule that applies to the cell **275**. More specifically, turning to the rule cube **670***b*, since cell rule B wildcards both the geographic dimension **271***g* and the product dimension **271***p*, all members **272***g* and **272***p* along those dimensions are effectively included by cell rule B. Therefore, the processor component **750** employs only the location of the cell **275** along the time dimension **271***t* to identify the corresponding cell **675** in the rule cube **670***b*. If that corresponding cell **675** in the rule cube **670***b* stores an indication of at least one cell rule (e.g., cell rule B), then the cell rule(s) indicated within that corresponding cell **675** is deemed to apply to the cell **275**. Turning to turning to the rule cube **670***cd*, since cell rules C and D both wildcard the geographic dimension **271***g*, all members **272***g* along the geographic dimension **271***g* are effectively included by both cell rules C and D. Therefore, the processor component **750** employs the location of the cell **275** along the product dimension **271***p* and the time dimension **271***t*, but not the geographic dimension **271***g*, to identify the corresponding cell **675** in the rule cube **670***cd*. If that corresponding cell **675** in the rule cube **670***b* stores an indication of at least one cell rule (e.g., one of cell rules C or D), then the cell rule(s) indicated within that corresponding cell **675** is deemed to apply to the cell **275**.

What cell rule(s) apply to the cell **275** represents a union of the indications stored in the corresponding cells **675** within each of the rule cubes **670***a*, **670***b* and **670***cd*. The cell **275** may be subject to no cell rules, may be subject to only cell rule indicated by a corresponding cell **675** within one of the rule cubes **670**, or may be subject to multiple cell rules indicated by one or more corresponding cells **675** of one or more of the rule cubes **670**. The processor component **750** may employ such a combined indication of what cell rule(s) apply to the cell **275** (if any) in determining whether to take any of a variety of actions with regard to that cell **275**. By way of example, the processor component **750** may selectively include the cell **275** in a request to the OLAP server **300** for a portion of the full data cube **270** (e.g., the data cube **370**) based on what cell rule(s) apply to that cell **275**. Alternatively, where the client device **700** has already been provided with at least a portion of the full data cube **270**, the processor component **750** may selectively provide access to the cell **275** based on what cell rule(s) apply. As yet another alternative, the processor component **750** may selectively modify a measure stored within the cell **275** based on what cell rule(s) apply.

The processor component **750** may operate the display **780** to present an operator of the client device **700** with an indication of what those cell rules are and/or what cells **275** are subject to cell rules. In particular, the processor component **750** may provide the operator with an indication of what cells are subject to cell rules imposing an access restriction that the client device **700** and/or the operator do not meet. By providing such information to the operator, the operator may be encouraged to request only a portion of the full data cube **270** of somewhat limited size, thereby alleviating the need to attempt to instantiate and/or transmit the entirety of the full data cube **270** to the client device **270**. Alternatively or additionally, the processor component **750** may limit any request subsequently made for the full data cube **270** to only portions that the rule cubes **670** indicate the client device **700** is authorized to receive such that the processor component **750** avoids requesting the entirety of the full data cube **270**.

It should be noted that, despite the specific depiction and discussion of the OLAP server **300** generating the data cube data **330** representing the data cube **370** and the rule server **500** separately generating the rule cube data **630** representing the rule cubes **670**, other embodiments are possible in which a single computing device performs both of these functions. It should also be noted that, despite the specific depiction of the client device **700** providing a user interface (UI) by which an operator may specify a portion of the full data cube **270** to request, other embodiments are possible in which the OLAP server **300** and/or the rule server **500** directly provide such a UI and thereby directly accept such operator input. In such embodiments, access restrictions may be based on the identity of the operator rather than what client device is requesting a data cube.

Each of the processor components **150**, **350**, **550** and **750** may include any of a wide variety of commercially available processors. Further, one or more of these processor components may include multiple processors, a multi-threaded processor, a multi-core processor (whether the multiple cores coexist on the same or separate dies), and/or a multi-processor architecture of some other variety by which multiple physically separate processors are linked.

In various embodiments, each of the storages **160**, **360**, **560** and **760** may be based on any of a wide variety of information storage technologies, including volatile technologies requiring the uninterrupted provision of electric power, and/or including technologies entailing the use of machine-readable storage media that may or may not be removable. Thus, each of these storages may include any of a wide variety of types (or combination of types) of storage device, including without limitation, read-only memory (ROM), random-access memory (RAM), dynamic RAM (DRAM), Double-Data-Rate DRAM (DDR-DRAM), synchronous DRAM (SDRAM), static RAM (SRAM), programmable ROM (PROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), flash memory, polymer memory (e.g., ferroelectric polymer memory), ovonic memory, phase change or ferroelectric memory, silicon-oxide-nitride-oxide-silicon (SONOS) memory, magnetic or optical cards, one or more individual ferromagnetic disk drives, or a plurality of storage devices organized into one or more arrays (e.g., multiple ferromagnetic disk drives organized into a Redundant Array of Independent Disks array, or RAID array). It should be noted that although each of these storages is depicted as a single block, one or more of these may include multiple storage devices that may be based on differing storage technologies. Thus, for example, one or more of each of these depicted storages may represent a combination of an optical drive or flash memory card reader by which programs and/or data may be stored and conveyed on some form of machine-readable storage media, a ferromagnetic disk drive to store programs and/or data locally for a relatively extended period, and one or more volatile solid state memory devices enabling relatively quick access to programs and/or data (e.g., SRAM or DRAM). It should also be noted that each of these storages may be made up of multiple storage components based on identical storage technology, but which may be maintained separately as a result of specialization in use (e.g., some DRAM devices employed as a main storage while other DRAM devices employed as a distinct frame buffer of a graphics controller).

In various embodiments, each of the interfaces **190**, **390**, **590** and **790** may employ any of a wide variety of communications technologies enabling these computing devices to be coupled to other devices as has been described. Each of these interfaces includes circuitry providing at least some of the requisite functionality to enable such coupling. However, each of these interfaces may also be at least partially implemented with sequences of instructions executed by corresponding ones of the processor components (e.g., to implement a protocol stack or other features). Where electrically and/or optically conductive cabling is employed, these interfaces may employ timings and/or protocols conforming to any of a variety of industry standards, including without limitation, RS-232C, RS-422, USB, Ethernet (IEEE-802.3) or IEEE-1394. Where the use of wireless transmissions is entailed, these interfaces may employ timings and/or protocols conforming to any of a variety of industry standards, including without limitation, IEEE 802.11a, 802.11b, 802.11g, 802.16, 802.20 (commonly referred to as "Mobile Broadband Wireless Access"); Bluetooth; ZigBee; or a cellular radiotelephone service such as GSM with General Packet Radio Service (GSM/GPRS), CDMA/1 xRTT, Enhanced Data Rates for Global Evolution (EDGE), Evolution Data Only/Optimized (EV-DO), Evolution For Data and Voice (EV-DV), High Speed Downlink Packet Access (HSDPA), High Speed Uplink Packet Access (HSUPA), 4G LTE, etc.

FIGS. **5** and **6** each illustrate a block diagram of a portion of an embodiment of the OLAP system **1000**. More specifically, FIG. **5** depicts aspects of the operating environment of one embodiment of the rule server **500** in which the processor component **550**, in executing the control routine **540**, may generate one or more reduced-sized rule cubes **670** (e.g., the rule cubes **670***a*, **670***b* and **670***cd*), and then transmit them to the client device **700** in response to a request for an indication of cell rules therefrom. FIG. **6** depicts aspects of the operating environment the client device **700** in which the processor component **750**, in executing the control routine **740**, transmits the request for an indication of cell rules to the rule server **500** and receives the reduced-sized rule cubes therefrom.

As recognizable to those skilled in the art, the control routines **140**, **340**, **540** and **740**, including the components of which each is composed, are selected to be operative on whatever type of processor or processors that are selected to implement applicable ones of the processor components **150**, **350**, **550** or **750**. In various embodiments, each of the control routines **140**, **340**, **540** and **740** may include one or more of an operating system, device drivers and/or application-level routines (e.g., so-called "software suites" provided on disc media, "applets" obtained from a remote server, etc.). Where an operating system is included, the operating system may be any of a variety of available operating systems appropriate for whatever corresponding ones of the processor components **150**, **350**, **550** or **750**. Where one or more device drivers are included, those device drivers may provide support for any of a variety of other components, whether hardware or software components, of corresponding ones of the computing devices **100***a-x*, **300**, **500** or **700**.

Referring to both FIGS. **5** and **6**, the control routines **540** and/or **740** may include a communications component **549** and/or **749** executable by the processor component **550** and/or **750** to operate the interface **590** and/or **790**, respectively, to transmit and receive exchange communications via the network **999** as has been described. Among the communications may be those conveying at least pieces of the raw data **130**, the data cube data **330** and/or the rule cube data **630** among the computing devices and/or servers **100**, **300**, **500** and/or **700** via the network **999**. As will be recognized by those skilled in the art, the communications components **549** and **749** are selected to be operable with whatever type of interface technology is selected to implement the interfaces **590** and **790**, respectively.

Turning more specifically to FIG. **5**, the control routine **540** may include a selection component **547** executable by the processor component **550** to receive indications of a request from another computing device (through the communications component **549**) for an indication of cell rules applicable to only a portion of the full data cube **270**. In response to receiving such a request, the selection component **547** limits retrieval of cell rules from the rule data **430** to rules applicable only to the portion of the full data cube **270** specified in the request. However, if the request received from the other computing device is for indications of cell rules applicable to the entirety of the full data cube **270**, then the selection component **547** retrieves indications of all cell rules applicable to the full data cube **270** from the rule data **430**. The selection component **547** may relay indications of whatever rules it retrieves to the grouping component **544**.

The control routine **540** may include a grouping component **544** executable by the processor component **550** to group together ones of the cell rules retrieved from the rule data **430** that have the same dimensional wildcarding configuration. The grouping component **544** provides any groups of cell rules, along with any cell rules that have not been grouped, to the generating component **546**.

The control routine **540** may include a grouping component **546** executable by the processor component **550** to generate one or more reduced-sized rule cubes (e.g., one or more of the rule cubes **670***a*, **670***b* and **670***cd*) from any cell rules grouped by the grouping component **544** and/or any cell rules retrieved from the rule data **430** that have not been grouped. In so doing, the generating component **546** generates the rule cube data **630** which represents the rule cubes **670** for transmission by the communications component **549** to another computing device.

Turning more specifically to FIG. **6**, the control routine **740** may include a user interface (UI) component **742** executable by the processor component **750** to operate the controls **720** and/or the display **780** to provide a user interface for an operator of the client device **700**. Upon receipt of the rule cube data **630** representing one or more reduced-sized rule cubes **670**, the UI component **742** may operate the display **780** to generate an indication to the operator of what cell rules apply to cells **275** of the full data cube **270**, or at least a portion thereof. Such an indication to the operator may be accompanied by an invitation for the operator to specify a portion of the full data cube **270** to request from the OLAP server **300**. Upon receipt of an indication via the controls **720** (or via another mechanism) of a specification of what portion of the full data cube **270** to request, the UI component may convey an indication of that specification to the filter component **746**. Upon subsequent receipt of data cube data, such as the data cube data **330** representing the data cube **370**, which may be a subset of the full data cube **270**, the UI component **742** may operate the display **780** to visually present at least a portion of that data cube data.

The control routine **740** may include a filter component **746** executable by the processor component **750** to employ indications of cell rules applicable to at least a portion of the full data cube **270** to modify a request by an operator of the client device **700** for at least a portion of the full data cube **270**. In so modifying the request, the filter component **746** removes from the request any portion of the full data cube **270** that the client device **700** and/or the particular operator thereof are not authorized to access according to the indication of cell rules provided by the rule cube data **330**. Following such filtering, the filter component **746** may relay the request to the communications component **749** to transmit to the OLAP server **300** via the interface **790**.

FIG. **7** illustrates one embodiment of a logic flow **2100**. The logic flow **2100** may be representative of some or all of the operations executed by one or more embodiments described herein. More specifically, the logic flow **2100** may illustrate operations performed by the processor component **550** in executing at least the control routine **540**, and/or performed by other component(s) of the rule server **500**.

At **2110**, a rule server of an online analytical processing (OLAP) system (e.g., the rule server **500** of the OLAP system **1000**) receives a request for an indication of cell rules applicable to a data cube (e.g., cell rules applicable to cells **275** of the full data cube **270**). As has been discussed, a client device (e.g., the client device **700**) may request such an indication of cell rules to employ in determining what portion(s) of the data cube to request from an OLAP server.

At **2120**, a processor component of the rule server performs a check of whether the request specifies cell rules applicable to only a portion of that data cube specified in the request. If the request is associated with only a portion, then the processor component filters out cell rules not applicable to the specified portion and groups cell rules applicable only to the specified portion based on having similar dimensional wildcarding configurations at **2122**. However, if the request is associated with the entirety of that data cube, then the processor component groups cell rules applicable to any portion of that data cube based on having similar dimensional wildcarding configurations at **2124**.

At **2130**, the processor component generates one or more reduced-sized rule cubes, one for each cell rule and/or for each group of cell rules having the same dimensional wildcarding configuration. At **2140**, the processor component transmits the one or more reduced-sized rule cubes to whatever device from which the request for an indication of cell rules was originally received.

FIG. **8** illustrates one embodiment of a logic flow **2200**. The logic flow **2200** may be representative of some or all of the operations executed by one or more embodiments described herein. More specifically, the logic flow **2200** may illustrate operations performed by the processor component **750** in executing at least the control routine **740**, and/or performed by other component(s) of the client device **700**.

At **2210**, a processor component of a client device of an OLAP system (e.g., the processor component **750** of the client device **700** of the OLAP system **1000**) operates an interface (e.g., the interface **790** to the network **999**) to transmit a request for an indication of cell rules applicable to a data cube (e.g., the full data cube **270**) to a rule server (e.g., the rule server **500**). At **2220**, the client device receives reduced-sized rule cubes in response to that transmitted request.

At **2230**, the processor component operates one or more components of a user interface (e.g., the controls **720** and/or the display **780**) to generate an audible and/or visual indication of the cell rule(s) indicated in each of the received rule cubes to an operator of the client device **700**. The processor component then awaits a response from the operator. At **2240**, the an indication of what portion of the data cube to request is received from the operator (e.g., from monitoring of the controls **720**).

At **2250**, the processor component uses the received rule cubes to filter the request for the portion of the data cube to remove from that request any portion of the data cube that the cell rules indicate a lack of authorization of the client device to have access. As has been discussed, this may be done despite having provided the operator of the client device with the opportunity to specify a portion of the data cube that does not include a portion to which the client device and/or the operator have no right to access, at all.

At **2260**, the processor component operates the interface to transmit the now filtered request for a portion of the data cube. At **2270**, the requested portion of the data cube is received.

FIG. **9** illustrates an embodiment of a processing architecture **3000** suitable for implementing various embodiments as previously described. More specifically, the processing architecture **3000** (or variants thereof) may be implemented as part of one or more of the computing devices and/or servers **100**, **300**, **500** or **700**. It should be noted that components of the processing architecture **3000** are given reference numbers in which the last two digits correspond to the last two digits of reference numbers of at least some of the components earlier depicted and described as part of the computing devices and/or servers **100**, **300**, **500** and **700**. This is done as an aid to correlating components of each.

The processing architecture **3000** includes various elements commonly employed in digital processing, including without limitation, one or more processors, multi-core processors, co-processors, memory units, chipsets, controllers, peripherals, interfaces, oscillators, timing devices, video cards, audio cards, multimedia input/output (I/O) components, power supplies, etc. As used in this application, the terms “system” and “component” are intended to refer to an entity of a computing device in which digital processing is carried out, that entity being hardware, a combination of hardware and software, software, or software in execution, examples of which are provided by this depicted exemplary processing architecture. For example, a component can be, but is not limited to being, a process running on a processor component, the processor component itself, a storage device (e.g., a hard disk drive, multiple storage drives in an array, etc.) that may employ an optical and/or magnetic storage medium, an software object, an executable sequence of instructions, a thread of execution, a program, and/or an entire computing device (e.g., an entire computer). By way of illustration, both an application running on a server and the server can be a component. One or more components can reside within a process and/or thread of execution, and a component can be localized on one computing device and/or distributed between two or more computing devices. Further, components may be communicatively coupled to each other by various types of communications media to coordinate operations. The coordination may involve the uni-directional or bi-directional exchange of information. For instance, the components may communicate information over the communications media. The information can be implemented as transmissions allocated to one or more electrical and/or optical conductors. A message (including a command, status, address or data message) may be one of such transmissions or may be a plurality of such transmissions, and may be transmitted either serially or substantially in parallel through any of a variety of connections and/or interfaces.

As depicted, in implementing the processing architecture **3000**, a computing device includes at least a processor component **950**, a storage **960**, an interface **990** to other devices, and a coupling **959**. As will be explained, depending on various aspects of a computing device implementing the processing architecture **3000**, including its intended use and/or conditions of use, such a computing device may further include additional components, such as without limitation, a display **980** and a display interface **985**.

The coupling **959** includes one or more buses, point-to-point interconnects, transceivers, buffers, crosspoint switches, and/or other conductors and/or logic that communicatively couples at least the processor component **950** to the storage **960**. Coupling **955** may further couple the processor component **950** to one or more of the interface **990**, the audio subsystem **970** and the display interface **985** (depending on which of these and/or other components are also present). With the processor component **950** being so coupled by couplings **955**, the processor component **950** is able to perform the various ones of the tasks described at length, above, for whichever one(s) of the aforedescribed computing devices implement the processing architecture **3000**. Coupling **959** may be implemented with any of a variety of technologies or combinations of technologies by which commands and/or data are optically and/or electrically conveyed. Further, at least portions of coupling **959** may employ timings and/or protocols conforming to any of a wide variety of industry standards, including without limitation, Accelerated Graphics Port (AGP), CardBus, Extended Industry Standard Architecture (E-ISA), Micro Channel Architecture (MCA), NuBus, Peripheral Component Interconnect (Extended) (PCI-X), PCI Express (PCI-E), Personal Computer Memory Card International Association (PCMCIA) bus, HyperTransport™, QuickPath, and the like.

As previously discussed, the processor component **950** (corresponding to the processor components **150**, **350**, **550** and/or **750**) may include any of a wide variety of commercially available processors, employing any of a wide variety of technologies and implemented with one or more cores physically combined in any of a number of ways.

As previously discussed, the storage **960** (corresponding to the storages **160**, **360**, **560** and/or **760**) may be made up of one or more distinct storage devices based on any of a wide variety of technologies or combinations of technologies. More specifically, as depicted, the storage **960** may include one or more of a volatile storage **961** (e.g., solid state storage based on one or more forms of RAM technology), a non-volatile storage **962** (e.g., solid state, ferromagnetic or other storage not requiring a constant provision of electric power to preserve their contents), and a removable media storage **963** (e.g., removable disc or solid state memory card storage by which information may be conveyed between computing devices). This depiction of the storage **960** as including multiple distinct types of storage is in recognition of the commonplace use of more than one type of storage device in computing devices in which one type provides relatively rapid reading and writing capabilities enabling more rapid manipulation of data by the processor component **950** (but in which a "volatile" technology may be used constantly requiring electric power) while another type provides relatively high density of non-volatile storage (but likely provides relatively slow reading and writing capabilities).

Given the often different characteristics of different storage devices employing different technologies, it is also commonplace for such different storage devices to be coupled to other portions of a computing device through different storage controllers coupled to their differing storage devices through different interfaces. By way of example, where the volatile storage **961** is present and is based on RAM technology, the volatile storage **961** may be communicatively coupled to coupling **959** through a storage controller **965*a*** providing an appropriate interface to the volatile storage **961** that perhaps employs row and column addressing, and where the storage controller **965*a*** may perform row refreshing and/or other maintenance tasks to aid in preserving information stored within the volatile storage **961**. By way of another example, where the non-volatile storage **962** is present and includes one or more ferromagnetic and/or solid-state disk drives, the non-volatile storage **962** may be communicatively coupled to coupling **959** through a storage controller **965*b*** providing an appropriate interface to the non-volatile storage **962** that perhaps employs addressing of blocks of information and/or of cylinders and sectors. By way of still another example, where the removable media storage **963** is present and includes one or more optical and/or solid-state disk drives employing one or more pieces of machine-readable storage medium **969**, the removable media storage **963** may be communicatively coupled to coupling **959** through a storage controller **965*c*** providing an appropriate interface to the removable media storage **963** that perhaps employs addressing of blocks of information, and where the storage controller **965*c*** may coordinate read, erase and write operations in a manner specific to extending the lifespan of the machine-readable storage medium **969**.

One or the other of the volatile storage **961** or the non-volatile storage **962** may include an article of manufacture in the form of a machine-readable storage media on which a routine including a sequence of instructions executable by the processor component **950** may be stored, depending on the technologies on which each is based. By way of example, where the non-volatile storage **962** includes ferromagnetic-based disk drives (e.g., so-called "hard drives"), each such disk drive typically employs one or more rotating platters on which a coating of magnetically responsive particles is deposited and magnetically oriented in various patterns to store information, such as a sequence of instructions, in a manner akin to storage medium such as a floppy diskette. By way of another example, the non-volatile storage **962** may be made up of banks of solid-state storage devices to store information, such as sequences of instructions, in a manner akin to a compact flash card. Again, it is commonplace to employ differing types of storage devices in a computing device at different times to store executable routines and/or data. Thus, a routine including a sequence of instructions to be executed by the processor component **950** may initially be stored on the machine-readable storage medium **969**, and the removable media storage **963** may be subsequently employed in copying that routine to the non-volatile storage **962** for longer term storage not requiring the continuing presence of the machine-readable storage medium **969** and/or the volatile storage **961** to enable more rapid access by the processor component **950** as that routine is executed.

As previously discussed, the interface **990** (corresponding to the interfaces **190**, **390**, **590** and/or **790**) may employ any of a variety of communications technologies corresponding to any of a variety of communications technologies that may be employed to communicatively couple a computing device to one or more other devices. Again, one or both of various forms of wired or wireless communications may be employed to enable the processor component **950** to interact with input/output devices (e.g., the depicted example keyboard **920** or printer **925**) and/or other computing devices, where such interaction may be through a network (e.g., the network **999**) or an interconnected set of networks. In recognition of the often greatly different character of multiple types of timings and/or protocols that must often be supported by any one computing device, the interface **990** is depicted as including multiple different interface controllers **995***a*, **995***b* and **995***c*. The interface controller **995***a* may employ any of a variety of types of wired digital serial interface or radio frequency wireless interface to receive serially transmitted messages from user input devices, such as the depicted keyboard **920**. The interface controller **995***b* may employ any of a variety of cabling-based or wireless timings and/or protocols to access other computing devices through the depicted network **999** (perhaps a network made up of one or more links, smaller networks, or perhaps the Internet). The interface **995***c* may employ any of a variety of electrically conductive cabling enabling the use of either serial or parallel transmission to convey data to the depicted printer **925**. Other examples of devices that may be communicatively coupled through one or more interface controllers of the interface **990** include, without limitation, microphones, remote controls, stylus pens, card readers, finger print readers, virtual reality interaction gloves, graphical input tablets, joysticks, other keyboards, retina scanners, the touch input component of touch screens, trackballs, various sensors, a camera or camera array to monitor movement of persons to accept commands and/or data provided by those persons via gestures and/or facial expressions, laser printers, inkjet printers, mechanical robots, milling machines, etc.

Where a computing device is communicatively coupled to (or perhaps, actually incorporates) a touch screen (e.g., the depicted example display **980**, corresponding to the touch screen **580**), such a computing device implementing the processing architecture **3000** may also include the display interface **985**. Although more generalized types of interface may be employed in communicatively coupling to a display (whether of the touch screen variety, or not), the somewhat specialized additional processing often required in visually displaying various forms of content on a display, as well as the somewhat specialized nature of the cabling-based interfaces used, often makes the provision of a distinct display interface desirable. Wired and/or wireless communications technologies that may be employed by the display interface **985** in a communicative coupling of the display **980** may make use of timings and/or protocols that conform to any of a variety of industry standards, including without limitation, any of a variety of analog video interfaces, Digital Video Interface (DVI), DisplayPort, etc.

Some systems may use Hadoop®, an open-source framework for storing and analyzing big data in a distributed computing environment. Some systems may use cloud computing, which can enable ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. Some grid systems may be implemented as a multi-node Hadoop® cluster, as understood by a person of skill in the art. Apache™ Hadoop®, for example, is an open-source software framework for distributed computing.

What has been described above includes examples of the disclosed architecture. It is, of course, not possible to describe every conceivable combination of components and/or methodologies, but one of ordinary skill in the art may recognize that many further combinations and permutations are possible. Accordingly, the novel architecture is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims.

The invention claimed is:

1. A computer-program product tangibly embodied in a non-transitory machine-readable storage medium, the computer-program product including instructions operable to cause a computing device to perform operations including:

select a first cell rule applicable to a data cube to include in a rule cube associated with the data cube based on applicability of the first cell rule to a selected portion of the data cube, the first cell rule comprising at least one of restricting read access to at least one cell of the data cube, restricting write access to the at least one cell, restricting access to change a measure or a pointer of the at least one cell, restricting a degree of change in at least one measure stored at the at least one cell during a calculation, imposing a minimum value on the at least one measure, and imposing a maximum value on the at least one measure;

analyze the first cell rule to identify at least one dimension of the data cube that is wildcarded in a first specification of the first cell rule of cells of the data cube that are subject to the first cell rule;

generate the rule cube indicating applicability of the first cell rule to the selected portion of the data cube, wherein a cell of the rule cube corresponds to multiple cells of the data cube, and wherein at least one dimension of the rule cube that corresponds to the at least one dimension of the data cube is reduced in length in comparison to a length of the at least one dimension of the data cube;

receive a request for an indication of cell rules applicable to the selected portion of the data cube; and

transmit the indication of the cell rules in response to the received request.

2. The computer-program product of claim **1**, the computing device caused to perform operations including:

analyze the first cell rule and a second cell rule applicable to the data cube to determine whether the first specification of the first cell rule and a second specification of the second cell rule wildcard identical dimensions of the data cube, wherein the second specification specifies cells of the data cube that are subject to the second cell rule; and

generate the rule cube to indicate applicability of the first and second cell rules to the selected portion of the data cube based on the determination.

3. The computer-program product of claim **2**, the computing device caused to perform operations including select the second cell rule to include in the rule cube based on applicability of the second cell rule to the selected portion of the data cube.

4. The computer-program product of claim **1**, the computing device caused to perform operations including:

receive a request via a network from another computing device for the selected portion of the data cube;

determine whether a cell of the rule cube stores an indication that the first cell rule denies access to any cell instantiated at a crossing within the selected portion of the data cube by the other computing device;

generate the selected portion of the data cube;

selectively instantiate a cell at the crossing within the selected portion of the data cube based on the determination; and

transmit the selected portion of the data cube to the other computing device via the network.

5. The computer-program product of claim **4**, the computing device caused to perform operations including:

aggregate detailed data to generate a measure, wherein operations to aggregate the detailed data comprise at least one of sum the detailed data, average the detailed data or take a weighted average of the detailed data; and

store the measure at the cell at the crossing within the selected portion of the data cube.

6. The computer-program product of claim **1**, the computing device caused to perform operations including:

perform a calculation that comprises storing a result as a measure of at least one cell of the selected portion of the data cube;

determine whether a cell of the rule cube that corresponds to the at least one cell stores an indication that the first cell rule does not permit storing the result as a measure of the at least one cell; and

selectively store the result as a measure of the at least one cell based on the determination.

7. The computer-program product of claim **1**, the computing device caused to perform operations including:

generate, on a display, an indication of the first cell rule; and

monitor a manually operable control for an indication of operation of the control to specify the selected portion of the data cube.

8. The computer-program product of claim **1**, the computing device caused to perform operations including:

analyze a cell of the rule cube that corresponds to at least one cell of the selected portion of the data cube to determine whether the first cell rule denies access to the at least one cell; and

selectively provide access to the at least one cell based on the determination.

9. A computer-implemented method comprising:

selecting, on a computing device, a first cell rule applicable to a data cube to include in a rule cube based on applicability of the first cell rule to a selected portion of the data cube, the first cell rule comprising at least one of restricting read access to at least one cell of the data cube, restricting write access to the at least one cell, restricting access to change a measure or a pointer of the at least one cell, restricting a degree of change in at least one measure stored at the at least one cell during a calculation, imposing a minimum value on the at least one measure, and imposing a maximum value on the at least one measure;

analyzing, on the computing device, the first cell rule to identify at least one dimension of the data cube that is wildcarded in a first specification of the first cell rule of cells of the data cube that are subject to the first cell rule;

generating, on the computing device, the rule cube indicating applicability of the first cell rule to the selected portion of the data cube, wherein a cell of the rule cube corresponds to multiple cells of the data cube, and wherein at least one dimension of the rule cube that corresponds to the at least one dimension of the data cube is reduced in length in comparison to a length of the at least one dimension of the data cube;

receiving, at the computing device, a request for an indication of cell rules applicable to the selected portion of the data cube; and

transmit the indication of the cell rules in response to the received request.

10. The computer-implemented method of claim **9**, comprising:

analyzing, on the computing device, the first cell rule and a second cell rule applicable to the data cube to determine whether the first specification of the first cell rule and a second specification of the second cell rule wildcard identical dimensions of the data cube, wherein the second specification specifies what cells of the data cube are subject to the second cell rule; and

generating, on the computing device, the rule cube to indicate applicability of the first and second cell rules to the selected portion of the data cube based on the determination.

11. The computer-implemented method of claim **10**, comprising selecting the second cell rule to include in the rule cube based on applicability of the second cell rule to the selected portion of the data cube.

12. The computer-implemented method of claim **9**, comprising:

receiving, at the computing device, a request via a network from another computing device for the selected portion of the data cube;

determining whether a cell of the rule cube stores an indication that the first cell rule denies access to any cell instantiated at a crossing within the selected portion of the data cube by the other computing device;

generating, on the computing device, the selected portion of the data cube;

selectively instantiating a cell at the crossing within the selected portion of the data cube based on the determination; and

transmitting the selected portion of the data cube to the other computing device via the network.

13. The computer-implemented method of claim **12**, comprising:

aggregating, on the computing device, detailed data to generate a measure, wherein aggregating the detailed data comprises at least one of summing the detailed data, averaging the detailed data or taking a weighted average of the detailed data; and

store the measure at the cell at the crossing within the selected portion of the data cube.

14. The computer-implemented method of claim **9**, comprising:

performing a calculation that comprises storing a result as a measure of at least one cell of the selected portion of the data cube;

determining whether a cell of the rule cube that corresponds to the at least one cell stores an indication that the first cell rule does not permit storing the result as a measure of the at least one cell; and

selectively store the result as a measure of the at least one cell based on the determination.

15. The computer-implemented method of claim **9**, comprising:

generating, on a display, an indication of the first cell rule; and monitoring a manually operable control for an indication of operation of the control to specify the selected portion of the data cube.

16. The computer-implemented method of claim **9**, comprising:

analyzing a cell of the rule cube that corresponds to at least one cell of the selected portion of the data cube to determine whether the first cell rule denies access to the at least one cell; and

selectively providing access to the at least one cell based on the determination.

17. An apparatus comprising:

a processor component;

a selection component for execution by the processor component to select a first cell rule applicable to a data cube based on applicability of the first cell rule to a selected portion of the data cube; and

a generating component for execution by the processor component to:

analyze the first cell rule to identify at least one dimension of the data cube that is wildcarded in a first specification of the first cell rule of cells of the data cube that are subject to the first cell rule, the first cell rule comprising at least one of restricting read access to at least one cell of the data cube, restricting write access to the at least one cell, restricting access to change a measure or a pointer of the at least one cell, restricting a degree of change in at least one measure stored at the at least one cell during a calculation, imposing a minimum value on the at least one measure, and imposing a maximum value on the at least one measure; and

generate a rule cube indicating applicability of the first cell rule to the selected portion of the data cube, wherein a cell of the rule cube corresponds to multiple cells of the data cube, and wherein at least one dimension of the rule cube that corresponds to the at least one dimension of the data cube is reduced in length in comparison to a length of the at least one dimension of the data cube; and

a communications component for execution by the processor component to receive a request for an indication of cell rules applicable to the selected portion of the data cube and transmit the indication of the cell rules in response to the received request.

18. The apparatus of claim **17**, comprising a grouping component to analyze the first cell rule and a second cell rule applicable to the data cube to determine whether the first specification of the first cell rule and a second specification of the second cell rule wildcard identical dimensions of the data cube, wherein:

the second specification specifies what cells of the data cube are subject to the second cell rule; and

the generating component generates the rule cube to indicate applicability of the first and second cell rules to the selected portion of the data cube based on the determination.

19. The apparatus of claim **18**, wherein the selection component selects the second cell rule based on applicability of the second cell rule to the selected portion of the data cube.

20. The apparatus of claim **17**, comprising:

a manually operable control; and

a user interface (UI) component for execution by the processor component to monitor the manually operable control for an indication of manual operation of the control to specify the selected portion of the data cube.

21. The apparatus of claim **20**, comprising a display, wherein the UI component generates, on the display, an indication of the first cell rule.

22. The apparatus of claim **20**, comprising a filter component for execution by the processor component to remove from the selected portion of the data cube a cell of the data cube based on whether a corresponding cell of the rule cube stores an indication that the first cell rule denies access to the cell of the data cube.

23. The apparatus of claim **17**, comprising a filter component for execution by the processor component to analyze a cell of the rule cube that corresponds to at least one cell of the selected portion of the data cube to determine whether the first cell rule denies access to the at least one cell, and to selectively provide access to the at least one cell based on the determination.

* * * * *